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LAKE SUNAPEE
WATER QUALITY MONITORING PROGRAM
1986

Freshwater Biology Group (FBG)

University of New Hampshire

Durham

Prepared For The

Lake Sunapee Protective Association

by

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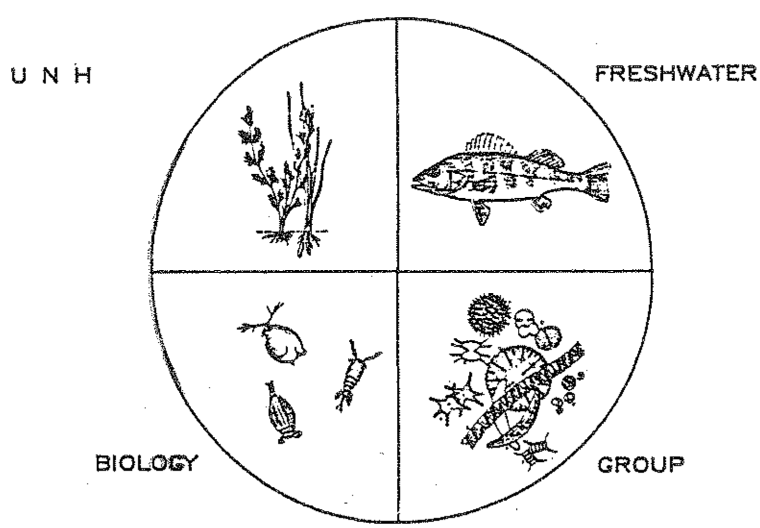
Lake Monitoring
A SERVICE PROGRAM BY THE



To obtain more information about the Freshwater Biology Group Lake Monitoring Program contact the FBG Coordinator (J. Schloss) at (603)-862-3848, Dr. Baker at 862-3845 or Dr. Haney at 862-2106.

PREFACE

This report contains the findings of a water quality survey of Lake Sunapee in Merrimack and Sullivan Counties, New Hampshire conducted in the summer of 1986 by the Freshwater Biology Group (FBG) of the University of New Hampshire at the request of the Lake Sunapee Protective Association (LSPA).

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1986 results as well as more detailed "Introduction" and "Results and Discussion" sections. Also included is a section on the methods and materials used by the Freshwater Biology Group.

Graphic display of data is included in addition to listings of data to aid visual perspective. Most figures display both spatial (between site locations on the same date) and temporal (between dates) relationships.

The appendices contain various supporting materials including a complete data summary, notes on the location of the sampling sites and a glossary of terms commonly used in this and other reports on water quality. The reader is referred to this last section as well as the materials cited in the references section if there is interest in learning more about the dynamics of fresh water systems.

ACKNOWLEDGEMENTS

The Freshwater Biology Group (FBG) applauds the Lake Sunapee Protective Association (LSPA) for their commitment to long-term monitoring of the water quality of Lake Sunapee.

We acknowledge Dr. Donald Bent for providing background information and previous reports. Dr. John Cassista directed us to tributary site locations and provided information on sampling strategies of the past. Bruce Putnam lent encouragement, ideas and recommendations. Frank Hammond, Executive Director of the LSPA helped in the development of this program and assisted in the field. Courtland Cross, President of the LSPA, was pilot during collection trips to the 29 lake sites; his knowledge of lake and shoreline use was invaluable.

The Freshwater Biology Group is a not-for-profit research program co-supervised by Dr. Alan Baker and Dr. James Haney. Members of the FBG summer field team, under the guidance and supervision of Dr. Baker and Dr. Haney, included Tracy Kenealy, Jeff Schloss, Patricia McCarthy, Lori Sommer, Steve Thomas and Zhanyang Guo. Jeff succeeded Tracy as coordinator of the LLMP, responsible for arranging the field trips, training and supervising the research team, quality assurance/control of the chemical analyses, data interpretation, and report writing.

The FBG acknowledges the University of New Hampshire for the partial funding of the coordinator position, as well as for the provision of laboratory and storage space. The UNH Office of Computer Services provided computer time and data storage allocations.

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NON-TECHNICAL SUMMARY

The general "health" of Lake Sunapee, based on standard water quality tests, is quite good. Water transparency is high, due to low concentrations of freshwater algae, and other suspended particles, and low levels of dissolved color. Nutrient concentrations in 1986 were generally at low levels and coliform bacteria at all lakeshore sites were well within the desired range for a class A water body. The composition of the microscopic aquatic plants and animals in Lake Sunapee was typical of open water plankton found in relatively clear unproductive lakes.

As with many northern New England lakes the lack of limestone in the bedrock results in low "buffering" against acidity. So far the pH (a measure of the acid activity) of Lake Sunapee is within the optimum range that most aquatic organisms require for successful growth and reproduction. (Wetzel 1983) The alkalinity, a measure of the lakes capacity to buffer against pH change, is at very low levels (3 to 4 mg per liter or stated another way 60 to 80 microequivalents per liter). This means that at times when acid addition to the lake is high (such as during the spring melt period) it is probable that the pH will decrease and the lakewater will become more acidic. Lakewater with a pH lower than 5.5 to 6.0 may have a deleterious effect on the more sensitive populations of aquatic organisms as well as an effect on the chemical processes within the lake. For example "heavy metal" concentrations may increase due to increased solubility and mobility. Alkalinity levels in 1986 may have been was lowest during heavy rain events. The tributaries feeding the lake generally had slightly higher alkalinities than the shore and deep sites of the lake, except for the inlets at the southwest end of the lake. The outlet at Sunapee Harbor had lower alkalinity than the rest of the lake on the last two dates sampled suggesting a net loss of buffering capacity as water is processed within the lake basin or some sort of local phenomenon. Early sampling immediately after spring ice melt should be undertaken to determine the extent of the pH change.

Chlorophyll a concentration, which is an indication of the standing crop of phytoplankton, was low throughout most of the lake. The Job's Creek area and the Newbury site at the south of the lake had concentrations of chlorophyll greater than the lake average on all three sampling dates. In July the two areas had chlorophyll concentrations that approached levels found in moderately productive lakes. The Newbury as well as the State Beach site also greater than average nutrient concentrations and slightly greater bacteria counts. The Job's Creek site had high concentrations of a phytoplankton species that is often found in productive waters enriched by septic pollution

(*Chrysochromulina*). Monitoring of the three areas will be important in future studies.

Dissolved color (brown stain) was greater at the Job's Creek and Herrick Cove shore sites, and the Soo-Nipi and Blodgett's Landing tributary sites. Water flowing from and into these sites had passed through wetland areas rich in tannins and lignins, the breakdown products from decomposing vegetative materials. Small increases in water color from natural organic stains are not considered to be detrimental to lake water quality.

The lakewater conductivity at Herrick Cove its tributary and the Georges Mill tributaries was high. Specific conductivity is an indicator of the dissolved salt concentration in lakewater. Generally, conductivity sources include runoff and erosion within the watershed, as well as cultural sources such as leaky septic systems and de-icing salts applied to highways and roads. Due to the proximity of the above mentioned sites to State Highways 103A and 11 and Interstate 89, the high conductivities are probably due to de-icing salt runoff. It may be useful to locate and examine the sources in more detail.

Extensive study of the three deep water stations at the north, central and southern areas of the lake was undertaken this year. The lake was thermally stratified throughout the summer. Low oxygen concentrations occurred in the bottom waters of the southern station in July. Oxygen in the lower waters is important for maintaining a healthy cold water fishery (such as trout and landlocked salmon) as well as limiting the release of nutrients from the sediments and minimizing the collection of organic matter on the lake bottom. The oxygen content of the bottom waters at all sites was greater in August and September. Analysis also suggests that populations of algae might be developing at intermediate depths depths. This is becoming a common situation in relatively clear lakes which are receiving some nutrient additions. More study of both phenomena is recommended.

With increased pressure to construct condominiums and housing developments in the lake watershed it is important to continue the water quality monitoring program. This as well as other studies have indicated areas of concern that should be examined in more detail. An important project of the monitoring program will be to develop a phosphorus (nutrient) budget that would quantify phosphorus loading from the six sub-watersheds surrounding Lake Sunapee. The phosphorus budget would be a useful management tool and would help predict the effects changes in land use, such as development. Stream discharge rates from the major tributaries should be measured to formulate a basic water budget for nutrient loading and to better interpret other water quality indicators. Greater understanding of Lake Sunapee and its physical, chemical and biological processes will provide information necessary for professional management of the lake.

INTRODUCTION

Importance of Long-term Monitoring

A major goal of a monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication; increases in the productivity of the lake due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern since New Hampshire receives large amounts of acid precipitation. Monthly sampling of a lake during a single summer provides information only on the variation that occurs. Short-term differences may be due to variations in weather or lake activity, or other chance events. The resulting short-term fluctuations may be unrelated to the actual long-term trend.

As an example, a 30 year study of a lake may indicate a long-term trend toward eutrophy (Fig. 1). Yet if only the data from a five year period (ie: Fig 1, years 1975-80) are examined, no apparent trends can be seen. If only two years are examined, the data suggest a decrease in eutrophy! Monitoring carried out monthly over the course of many summers can provide the information required to distinguish between short-term fluctuation ("noise") and long-term trends ("signal"). To that end, the lake must establish a long-term data base.

The number of seasons it takes to discern between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long term data base will indicate that the water quality of the lake has worsened, improved, or remained the same. As more data is collected prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of the lake.

Purpose and Scope of This Study

This was the first year of monitoring of Lake Sunapee by the Freshwater Biology Group. The program of sampling was designed to continue adding data to the long-term data base established by the Lake Sunapee Protective Association, initiate new water quality tests, provide a more in-depth analysis of certain lake sites, and evaluate the choice of sampling stations. In the design of this current sampling program previous studies of Lake Sunapee were utilized including the edited version of the 1972 Cortell Report, the survey by the New Hampshire Water Supply and Pollution Control Commission (1979) and the Peck/IEP report (1981). It is not within the scope of this work to compare historical data. The purpose of this report is to discuss results of the 1986 monitoring with emphasis on current condition of Lake Sunapee including the extent of eutrophication and the lake's susceptibility to increasing acid precipitation.

METHODS OF THE FRESHWATER BIOLOGY GROUP

In 1986 the Freshwater Biology Group (FBG) research team took 3 trips to Lake Sunapee and conducted several tests which included measurements of sunlight penetration into the water, dissolved oxygen, alkalinity, free (unbound) carbon dioxide, pH, specific conductivity, chlorophyll <u>a</u>, dissolved color, total phosphorus, total and fecal coliform bacteria, and a survey of the microscopic plants (phytoplankton) and animals (zooplankton).

<u>Field and Laboratory Methods</u>

At the deep water stations on the lake, a dissolved oxygen and temperature profile was taken using a Yellow Springs Instruments Model 54A Oxygen/Temperature meter with a submersible probe. Readings were taken at one-meter intervals throughout the epilimnion and hypolimnion, and at one-half meter intervals through the metalimnion.

Sunlight and skylight penetration into the water was measured with a Whitney submersible photometer model LMA-8A, off the sunny side of the boat. The coefficient of light extinction was calculated from the relative light intensities measured.

Samples of lake water to be analyzed for dissolved oxygen, alkalinity, free (unbound) carbon dioxide, pH, and specific conductivity were collected with a 3-liter Van Dorn bottle at depths that represented the surface, mid-epilimnion, metalimnion, and hypolimnion of the three deep water sites. Shore lake water samples were collected 0.5 to 1 meter below the lake surface. Alkalinity, free carbon dioxide, and pH samples were stored on ice in 250 milliliter polyethylene bottles and were analyzed in the field generally within 1 to 2 hours of sampling. Specific conductivity was measured in the FBG lab at room temperature.

In addition to the oxygen profile taken, the dissolved oxygen (DO) concentration of specific lakewater samples (epilimnetic and hypolimnetic) were determined chemically with the azide modification of the Winkler method (EPA 1979). The precision of the method provides a standard for the electronic probe. Water is collected in 350 ml biological oxygen demand (BOD) bottles and fixed with two reagents, manganese sulfate and alkaline-iodide-azide. A loose precipitate (floc) of manganic hydroxide is formed that is equivalent to all dissolved oxygen originally present in the sample. Concentrated sulphuric acid is added to the bottle which causes a stoichiometric release of dissolved iodine equal to the original amount of dissolved oxygen present. A known quantity of sample is then titrated to an end point using .0250N phenylarsine oxide titrant (similar to sodium thiosulphate which may also be used) and a starch indicator solution. The end point is reached when the purple colored iodine-starch complex is reduced and the solution becomes colorless . The amount of titrant added was recorded to the nearest 0.1 ml and concentrations are reported to the nearest 0.2 milligrams dissolved oxygen per liter.

To determine the alkalinity, lake water samples were titrated with 0.002 N sulphuric acid in the presence of the indicator methyl red/bromocresol green to a pH of 5.1 (grey endpoint) and 4.6 (pink endpoint). The amount of titrant used (dilute sulphuric acid) was recorded to the nearest 0.1 ml, equivalent to milligrams of calcium carbonate per liter. Values reported can be converted to microequivalents of calcium carbonate using a multiplication factor of 20.

"Free" carbon dioxide concentration was determined by titrating the fresh lakewater samples with 0.0027 N sodium hydroxide to a final endpoint pH of 8.3, in the presence of the indicator dye phenolphthalein.

Lakewater pH was measured with a digital pH meter (Beckman model phi 44) equipped with a combination probe (Orion Co.) and an automatic temperature compensating probe. The meter was calibrated with pH 4 and pH 7 buffer solutions and then the probe was allowed to equilibrate in the lake water for at least thirty minutes prior to sample analysis.

Specific conductivity was measured with a Barnstead Conductivity Bridge Model PM-70CB , with a model B-10 probe (cell constant = 1.0). Corrections were made for sample temperatures with a standard curve of potassium chloride solution conductivity versus temperature. Results are reported as micro-Siemens (uS; where uS equals umho cm-2) standardized to 18o Centigrade.

Chlorophyll samples were filtered through a 0.45 micron membrane filter and air-dried in the dark until analysis. The chlorophyll a content was analyzed by extracting the chlorophyll with a 95% acetone solution saturated with magnesium carbonate. The samples were then centrifuged and their light absorbance read at two standard wavelengths (663 and 750 nanometers) with a Baush and Lomb model 710 spectrophotometer equipped with 50mm cuvettes. An absorptivity value of 84 gm liter-1 cm-1 (Vollenweider 1969) was used for calculating the concentrations.

Dissolved color of the filtrate from chlorophyll filtrations was determined by reading the absorbance of the samples at two different wavelengths (440 and 493 nanometers) in a 50mm light path. The two readings were converted to the more widely used platinum cobalt color values with our standard curves of the absorbance of chloroplatinate.

Phosphorus samples were preserved with 1.0 milliliter of concentrated sulphuric acid and refrigerated until analysis. To determine the total phosphorus content, ammonium persulfate and 11 N sulphuric acid was added to digest the total phosphorus, and the samples were autoclaved for thirty minutes at 250 to 260 degrees C. Reagents included potassium antimony tartrate, ammonium molybdate, and a solution of ascorbic acid mixed fresh before each sample run (E.P.A. 1979). Absorbance of the blue phosphorus complex was measured with the spectrophotometer at 650 nanometers. A standard curve of the absorbance of a potassium phosphate (monobasic) solution was used to convert the readings to total phosphorus concentrations. Each sample was analyzed twice and an average of the two values was recorded as the phosphorus content in parts per billion (ppb).

At selected stations and depths 60 ml of water from the Van Dorn was collected for phytoplankton analysis. On some occasions an integrated sample was collected with a vertical tube sampler lowered through the epilimnion. Phytoplankton samples were preserved with iodine (Lugol's solution) immediately after collection. Algae were later identified and counted with an inverted microscope after settling for 24 hours in 5 or 10 ml counting chambers. At least 200 individual algal "units" were counted with a modified scan technique (Baker, 1973). Phytoplankton are reported to species level whenever possible.

At the deep water stations zooplankton samples were collected with a plankton net (30 centimeter diameter, 150 micron porosity) towed vertically through the oxygenated portion of the water (>0.5 ppm oxygen). Samples were immediately preserved in a 4% formalin-sucrose solution (Haney and Hall, 1973). Organisms were identified to species whenever possible. Subsampling, whenever necessary, was done with a 1 ml Hensen-Stemple pipette. Repeated subsamples were analyzed until at least 100 organisms were counted.

Samples of coliform bacteria were collected at the shore sites, tributary stations and open water sites. Samples were collected in sterile 250 milliliter sample bottles with hoods and immediately placed in a field cooler. At the FBG lab in Durham, samples were filtered through sterile filter assemblies onto 47mm diameter, 0.45 micrometer pore size, membrane filters (Millipore HA) under low vacuum (aspirator). On 2 September samples were filtered through bacteriological "field monitors" which consisted of a 37mm diameter HA filter, absorbent pad, and flow through petri dish assembly. The "field monitors" enabled filtration to take place while we traveled between lake stations, maintained sterile conditions, saved time in processing samples and made time consuming filter holder sterilization unnecessary. A sample was filtered into the "field monitor" through a pre-sterilized delivery tube using a syringe for vacuum. Results of samples run with both the previous technique and the "field monitors" were identical. Total coliform bacteria were incubated in MF-Endo broth at 35o Centigrade for 24 hours. Fecal coliform bacteria were incubated in MF-C broth at 44.5o Centigrade for 24 hours. All sampling, incubation and counting techniques used are referenced in Standard Methods (APHA 1975). Results are reported as number of bacteria per 100 ml.

Data Analysis

All field and laboratory data was filed and stored on the FBG computerized data management system that utilizes a mainframe DEC VAX-8650 computer and an IBM compatible micro-computer (Zenith Data Systems 158). With full use of relational data bases, such as S1032 and Dbase III, data can be retrieved easily by date, station, or by parameter for within-lake comparison, or between-lake comparisons with other lake data bases (Lakes Lay Monitoring Program, New Hampshire Water Supply and Pollution Control, N.H. Fish and Game, EPA Surface Water Survey and others). Spreadsheet, statistics and graphics packages on both the mainframe and micro-computer enable data analysis and presentation.

Although it is not within the scope of this report, the FBG also stores historical information to help estimate trends in lake water quality.

Trophic boundaries of Forsberg and Ryding (1980) of transparency, chlorophyll a, and total phosphorus are used as criteria in discussions of the trophic state of Lake Sunapee. Phytoplankton are reported both as species and classes. Crustacean zooplankton were classified into one of four categories depending on their size (large or small) and their feeding preferences (herbivore or predator) with a modified version of criteria from Sprules (1980). The differences in abundance between the different groups allow for a more complete description of the zooplankton community and the trophic classification of lakes.

RESULTS AND DISCUSSION

Site Locations

On three dates, July 3, August 3 and September 2 the Freshwater Biology Group collected surficial lakewater at 26 near-shore sites, 7 tributary sites, 1 outlet site and 3 deepwater stations. Locations and site numbering was similar to those used in previous years at Lake Sunapee by Bent and Cassista. Sites include areas near inlets or other areas of concern such as beaches and developments. Numbering starts at Georges Mills and continues counter-clockwise around the lake (Fig. 2). The tributary sites represent six of the larger inlets to the lake (T-2 through T-7) while T-8 was chosen as a representative stream in the Herrick Cove area that was at a convenient location. The lake outlet site was sampled immediately above the dam at the water level gauge (site T-1). Sites T-2 through T-7 are tributaries (except T-8) located clockwise around the lake. Deepwater stations that were investigated more extensively were the northern (site 22A), central (site 22) and southern (site 22B) basins of the lake. An attempt was made to sample every site of the lake as time, weather conditions and materials permitted.

Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of secchi disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

Secchi disk measurements were taken only at the three deep stations since the shore sites were usually too shallow and the disk would hit bottom before it could disappear. Table 1 displays the results from the three dates. Secchi disk depth and hence, the transparency of the water, increased as the summer progressed. Precipitation was heavy during the summer months of 1986. Greater amounts of surface runoff, in combination with high winds stirring up water in the shallows, were probably responsible for an elevation in phytoplankton concentrations and dissolved color, and thus, a decrease in lakewater transparency in July.

TABLE 1 WATER TRANSPARENCY OF DEEPWATER SITES, LAKE SUNAPEE

SECCHI DISK DEPTH IN METERS

SITE	3 July	3 August	2 September
22	6.1	8.7	9.1
22A	---	8.0	10.9
22B	6.2	9.2	9.8

Transparency values of greater than 4 meters are typical of clear, less productive lakes. Lake Sunapee had a relatively high transparency throughout the summer. The 10.9 m value at the northern station (22A) was one of the highest values recorded by the Freshwater Biology Group in 1986, at all lakes observed.

Chlorophyll a

The chlorophyll a concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. Eutrophic lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Summer chlorophyll a concentrations average above 7 mg m-3. Oligotrophic lakes have low productivity and low nutrient levels and average summer chlorophyll a concentrations are generally less than 3 mg m-3. Mesotrophic lakes are intermediate in productivity with concentrations of chlorophyll a generally between 3 mg m-3 and 7 mg m-3.

Average chlorophyll a concentrations at the near-shore and deep sites on the three sampling dates (1.3, 0.4 and 0.9 mg m-3 respectively) were within the range typical of clear oligotrophic lakes (Fig. 3). Concentrations at two lake shore sites, Job's Creek (site 3) and Newbury (sites 16, 17) were consistently higher than the lake average on all three sampling dates. These sites approached mesotrophic concentrations in July (2.6 mg m-3 at site 3 and 2.3 mg m-3 at site 16).

On 3 August, chlorophyll concentration at the tributary sites were similar to the lake average except for a concentration of 15.3 mg m-3 at T-5 (Fig. 4A). Contamination of the sample with vegetative material from the stream bottom is a probable cause of this high value. On 2 September concentrations at all sites except T-6 were somewhat above the lake average but not sufficiently to be a cause for concern. There was no evidence of import of nuisance blooms of algae.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from humic substances, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters.

The historical lake average of lake color from 1972 to present is approximately 3 ptu (chloroplatinate units). Higher color values in July were probably related to heavy rain during early summer. Some of the depression in water transparency at that time is attributable to the increased color. On July 3 color was highest at Dewey Beach (site 8), 31 ptu, followed by Fisher Bay (site 12) and Job's Creek (site 3) (Fig. 5). Site 8 is fed by Bairds Brook which along with Job's Creek drains a wetland area high in humic materials. Site 12 is fed by Red Water Creek which has been known to contain some iron as well as dissolved humic matter. In August and September levels of dissolved color decreased to more typical levels (less than 5 ptu). The Herrick Cove area maintained higher than average dissolved color during this time, as did the Newbury site. To put concentrations in perspective, New Hampshire Lakes studied in 1986 by the Freshwater Biology Group had a range of dissolved color of from essentially 0 ptu (Newfound Lake, Squam Lake and Silver Lake of Madison, for example) to 117 ptu (Scruton Pond in Barrington) with an unweighted average of 17 ptu. It is apparent that the water color in Lake Sunapee is relatively low.

Lakewater color was higher at the tributary sites sampled in 3 August and 2 September (Fig. 4B) than at the shore sites. Also, while color was relatively high at the eastern-central tributaries (T-4 and T-5), it was relatively low at the shore sites closest to them (20 and 21). This is a good example of the dilution effect that occurs as tributaries mix with a lake as large as Sunapee.

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources include primarily anthropogenic activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton.

The average concentrations of total phosphorus was 12.2 ppb (equivalent to 0.012 mg per liter or 0.012 ppm) on July 3 (Fig. 6). Heavy rainfall and runoff of early summer, combined with the physical disturbances associated with storm events, may have contributed phosphorus by erosion and by resuspension of lake sediments. Higher concentrations occurred in the northern and southern sections while central lake stations had lower values. Concentrations typical of mesotrophic lakes occurred at Newbury, Job's Creek and southern State Park sites. During the other sampling dates concentrations fell to more typical oligotrophic levels. Averages were .002 ppm on 3 August and 2 September.

Phosphorus concentration was relatively high at tributary sites (Fig. 7) particularly at George's Mill (T-2), Soo-Nipi (T-4), Blodgett's Landing (T-5) and State Beach (T-7) sites. As at the shore sites, concentrations declined in late summer and the average summer concentrations are within the range typical of oligotrophic systems.

pH

The pH is a way of expressing the acidic level of lake water, and is measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (ie: changes in 1 pH unit reflect an order of magnitude difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

The pH levels of Lake Sunapee surface water were in the range 6.4 - 7.0 units with the majority of values above 6.8. Lower pH values occurred at tributary sites T-4 through T-7 on 3 July and 3 August (range of 5.8 to 6.6 units). Tributary values reported for 2 September are probably unreliable due to a pH probe dysfunction, while all lakewater values are reliable.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada (Schindler et al 1985) gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the Freshwater Biology Group includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (grey color of dye) approximates values obtained with the recently-accepted Gran-Titration while the second endpoint (pink dye color) approximates the alkalinity values recorded historically with the methyl-orange endpoint method. For more detail on methods, please see the Methods and Materials section in this report, also EPA (1972) and current National Water Quality Survey protocol publications.

Alkalinity levels at all lake sites were very low, with a range of 3 to 4 mg per liter (Fig. 8). The outlet site had lower alkalinity (Fig. 9) than inlet and open water lake sites suggesting a local phenomenon unrelated to the remainder of the lake. Alkalinity levels at the tributary sites were low to moderate with greater alkalinity occurring at the Herrick's Cove (T-8) and Otter Pond (T-3) inlets (Fig. 9). The average alkalinity of lakes throughout New Hampshire is approximately 9 mg per liter (Baker, unpublished) while the average alkalinity of the lakes studied by the Freshwater Biology Group in 1986 was 6.0 mg per liter with a range of 0.6 to 14.7 mg per liter.

Specific Conductivity

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and de-icing salt runoff from highways can cause high conductivity values. Lake site surface conductivity values had a range of 55 to 57 uS on 3 July, 69 to 74 uS on 3 August, and 69 to 81 uS on 2 September (see appendix). Lower conductivity in July reflects the freshwater runoff resulting from the early summer rain events. The average conductivity of all lakes studied by the Freshwater Biology Group in 1986 was 88 uS and had a range of 29 to 239 uS.

Conductivity values at George's Mill (sites T2 and T3), State Beach (T-7) and Herrick Cove (T-8) were consistently higher in conductivity than lake averages on all three dates (Fig. 10). Conductivity was slightly higher on August 3 and September 2 at Soo-Nipi (site T-4), and consistently lower at Pine Cliff (site T-6). Historically, sites at George's Mill and Herrick Cove have had high conductivities attributed to run-off from de-icing salts. Because salt water tends to sink, conductivity profiles of the two sites should be initiated in next years sampling. Sources of conductivity for the tributaries might also be examined. High concentrations of dissolved salts can restrict the complete turnover of lake basins as well as affect the health and distribution of aquatic organisms.

Stratification in the Deep Water Sites

Profiles of temperature for the three deep sites studied (Fig.11) show distinct patterns of temperature stratification where a layer of warmer water (the epilimnion) overlies a deeper layer of cold water (hypolimnion). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the thermocline or metalimnion. Temperature profiles of Lake Sunapee are typical of deep water, clear lakes.

Dissolved oxygen profiles (Fig. 12) indicate declining oxygen concentrations in the lower waters. Particularly low concentrations occurred on 3 July at sites 22 and 22B. Site 22A had low concentrations on 3 August. Oxygen in the lower waters is important for maintaining a healthy, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter in the cool deep waters. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Figure 13 provides a summary of the conditions at deep water site 22 during 3 July and 2 September. Temperature profiles indicate an increase in the extent of the hypolimnion as the summer progressed. On 3 July dissolved oxygen was lower and carbon dioxide was greater in the bottom waters than on 2 September. The pH was slightly lower in the deeper waters most likely due to the increase in carbon dioxide. Generally in more productive systems, as the summer progresses bottom waters are depleted of oxygen, and carbon dioxide increases. Early summer precipitation might have caused the run-off of substances that create a chemical or biological oxygen demand on the bottom waters of Lake Sunapee. Sampling next season should help determine if this is a reoccurring phenomenon.

Underwater Light

Underwater light available to photosynthetic organisms penetrates to deep depths in lake Sunapee (Fig. 14). The photic zone of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the level where light is reduced, by the absorption and scattering properties of the lake water, to one percent of the surface intensity. The one percent depth is sometimes termed the compensation depth. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation.

On 3 July sunlight was reduced by storm clouds and the actual extent of the photic zone could not be determined while clear skies prevailed on 3 August and 2 September. The compensation depth on 3 August was between 10 and 11 meters. Light penetrated the deepest on 2 September where the one percent depth was 13.5 to 15 meters.

Phytoplankton

The planktonic community includes microbial organisms that represent diverse life forms, including photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae. Plankton were collected on three dates in 1986 (3 July, 3 August, and 2 September) at three deep sites in Lake Sunapee (22, 22A and 22B). The zooplankton are considered below in a seperate section.

Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the three collection dates and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton in Lake Sunapee was typical of open-water plankton in relatively clear and unproductive lakewater, with generally low alkalinity. For example, in the surface or epilimnetic layers of Lake Sunapee the dominant algae were the Chrysophyceae, a class of "golden" or "golden-brown" photosynthetic organisms (Figs.15-17). Among the most abundant of the golden algae was the population of a minute flagellate, *Chrysochromulina* cf. *parva*, found in a large number of lakes in New England and Ontario. Changes in this population may be related to levels of organic pollutants, as blooms have been found in Northwood Lake for several years. In that lake, a local "honey wagon" operator was discovered dumping his truck load in the lake on several occasions before he was dissuaded from the practice.

Another dominant golden alga was Kephyrion sp., generally ignored or overlooked in lakewater analyses, and about which little is known. By early September the dominance in the northern region of the lake (site 22A) shifted to a colonial golden alga, Chrysosphaerella longispina, while Chrysochromulina and Kephyrion remained dominant in the southern region (site 22B). Noteworthy because of their lack of dominance were species of Dinobryon and Mallomonas, generally found in New Hampshire lakes at higher concentrations.

An exception to the chrysophycean dominance was found in early July at site 22, where the Chlorophyceae (green algae) and Cyanobacteria (blue-green bacteria) were more abundant (Fig. 16). The latter two groups tend to be more abundant in nutrient enriched lakes, but their concentration in Lake Sunapee was relatively low. It is of interest that the Chlorophyceae and Cyanobacteria were also dominant in the deeper lakewater layers. Frequently members of these two groups will form densely populated "green blankets" or microstrata at depths where the temperature and density gradient occurs, the thermocline. The presence, persistence, density and composition of such layers appears to be related to the nutrient status of a lake, and it is useful to monitor them, along with the surface water community.

The dominant cyanobacteria were populations of the colonial genera Aphanocapsa and Aphanothece, and at greater depth the colonial Merismopedia. Such colonies are small and unobtrusive, rarely if ever a cause for concern about lakewater quality, and frequently found in the most remote, pristine lakes. The larger organisms among the cyanobacteria were conspicuously sparse or missing (Oscillatoria, Microcystis, Aphanizomenon, Anabaena, and Lyngbya spp.).

The dominant chlorophycean populations were Ankistrodesmus falcatus and Oocystis sp., members of the chlorococcoid algae that tend to be indicators of nutrient enriched waters when they appear in larger numbers. Their presence and concentration in Lake Sunapee should be watched during the next few years for signs of any increase in concentration.

Other groups of phytoplankton were present but less abundant, including the Euglenophyceae, Bacillariophyceae, Cryptophyceae and Dinophyceae. Many members of these four classes are indicators of enriched or polluted lakewater, thus their relatively low concentration in Lake Sunapee is a positive condition. Some species, especially members of the

Bacillariophyceae or "diatoms", tend to be most abundant in April-May and October-November, thus summer sampling may have underestimated their contribution during the spring and fall. The cryptomonads such as Cryptomonas and Chroomonas are essentially ubiquitous, and populations of these poorly-understood flagellates are often concentrated in acidic waters such as bogs.

The total counts of planktonic algae were in the range two to three thousand per milliliter (2-3x103 ml-1). The greatest concentrations in the surface waters occurred in early July (Fig. 17). In the northern and central regions of Lake Sunapee a metalimnetic maximum developed by early September, with more than two times more organisms in the thermocline than at the surface (Fig. 17 and 18). In contrast at the southern region (site 22B), most of the organisms were at the surface. While it is not yet clear what these differences in distribution between the regions of the lake suggest, they are noted for future study.

Concentrations of a few thousand organisms per milliliter are a second indication, along with the specific composition of the plankton, that the trophic status of Lake Sunapee is moderate, or mesotrophic. Careful microscopy of the type utilized in this study can discern as few as 10 to 50 cells ml-1, fewer than are found in some of the most unproductive waters, or as many as 106 - 107 cells ml-1, as found in highly productive, nutrient-enriched eutrophic lakes.

While the total counts of phytoplankton in this 1986 study are quite a bit higher than those reported in the early 1970's, the difference may be in large part attributable to the techniques employed. In this study, "whole lakewater" was analyzed. It is unclear whether the earlier Cortell study included high magnification, and whether "whole" or "filtered" (through a plankton net) lakewater was analyzed. The trend among plankton analysts is to avoid use of any nets for phytoplankton analysis, because the majority of organisms in this group are too small to be captured by net porosity greater than 20 microns. Most studies prior to the 1980's included lakewater filtered through nets with porosity greater than 50 microns, thus the vast majority of phytoplankton cells and colonies were lost and not counted. In general, when whole lakewater is taken into consideration as in this study, ultra-clean lakes with minimal nutrient loading tend to support fewer than about 500 organisms per milliliter, mesotrophic systems support perhaps 2000 to 4000, and eutrophic lakes can support in excess of 10,000 (even millions) of organisms per milliliter. Thus, the combination of quantity per milliliter and quality or distribution of species is a useful and sensitive indicator of the trophic state of a lake. Thus, Lake Sunapee can be said to be within the oligotrophic to mesotrophic range on this basis.

Indicator Bacteria

Coliform bacteria in water indicate the possibility of fecal contamination. Although they are usually considered harmless to humans, they are much easier to test for than harmful pathogenic enteric bacteria (Salmonella, Shigella etc.) and viruses that may be present in fecal material. Total coliform includes all coliform bacteria which arise from the gut of animals or from vegetative materials. Fecal coliform are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism fecal streptococcus (sometimes referred to as enterococcus) has also been monitored in the past at Lake Sunapee. The ratio of fecal coliform to fecal strep may be useful in suggesting the animal source of the contamination. In consultation with Dr. L. W. Slanetz, a pioneer in the membrane filter technique for quantifying bacteria, it was advised not to continue the testing since fecal counts are generally low at Lake Sunapee and the ratio method only remains valid for a short period after the pollution takes place. Some fecal strep samples may be taken in the coming season at those sights with higher counts to maintain historical data continuity.

The results of 1986 sampling are shown on Table 2. Desirable levels for a Class A water body is less than 50 organisms per 100 milliliters. All lake sites had very low counts on all three sampling dates. The highest count of fecal coliform for a lake site was 7 per 100 ml at the Newbury (site 16). Counts were greater at most tributary sites especially the State Beach (T-7) site which had counts greater than 20 organisms per 100 ml on the three sampling dates. While counts were higher in the tributaries the effect on the lake is probably not severe since lake sites near sampled tributary sites did not have significantly different counts when compared to deep water lake sites.

TABLE 2 Total and Fecal Coliform Bacteria Densities for Lake Sunapee 1986. Reported as numbers per 100 ml.

DATE:	3 July	3 August	2 September	
	Total	Fecal	Total	Fecal
SITE	Coliform	Coliform	Coliform	Coliform
1	--	--	6*	2
2	3	--	--	<1
3	6	1	7*	1
4	CG	<1	--	--
5	4	<1	--	<1
6	2	<1	--	<1
7	3	1	<1	<1
8	6	<1	--	<1
9	5	2	--	--
10	CG	3	--	<1
11	7	<1	--	<1
11A	--	2	--	--
12	5	3	--	<1
13	2	<1	--	--
14	5	1	<1	<1
15	6	1	--	<1
16	5	7	<1	1
17	7	3	<1*	<1
18	6	<1	1	<1
19	3	2	--	<1
19A	<1	2	--	--
20	9	1	--	1
21	6	<1	<1	<1
22	2	<1	--	<1
22A	<1	<1	--	<1
22B	3	3	<1	--
23	1	<1	<1*	--
24	1	1	2*	1
25	3	1	--	<1
T1	11	2	4*	<1
T2	TNTC	3	<1*	<1
T3	TNTC	28	26*	8
T4	TNTC	24	10*	8
T5	TNTC	15	<1*	<1
T6	55	1	<1*	<1
T7	TNTC	21*	76*	42
T8	42	60*	18*	22

CG = Confluent Growth TNTC = Too Numerous to Count
* = Samples had high numbers of non-coliform bacteria (between 400 and 1000 per 100 ml). Total coliform may be underestimated due to overcrowding on the filter.

Zooplankton

There are three groups of zooplankton that are generally dominant in lakes: the protozoa, rotifers and crustaceans. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints made it necessary to sample only the larger zooplankton (macrozooplankton; larger than 150 microns). Thus, zooplankton analysis was restricted only to the larger crustaceans. The crustaceans can be divided into two groups, the cladocerans (which include the "water fleas") and the copepods.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake.

As discussed above for phytoplankton, zooplankton undergo seasonal population cycles and the results discussed below are most representative of the three collection dates and not necessarily of other times during the ice-free season, especially during the early spring and late fall.

The composition and concentration of macrozooplankton crustaceans in Lake Sunapee was typical of open water plankton in relatively clear and unproductive lakes. Among the most abundant animals on 3 July at all deep sites (Fig. 18) and 3 August at 22A (Fig. 19) were two species of the relatively large herbivorous cladoceran *Daphnia* (*D. dubia* and *D. catawba*). The small herbivorus calanoid copepods were generally subdominant in all samples, and accounted for 50 percent of the community at the southern site (22B) on 3 August.

The predatory cyclopoid copepods remained at the same relative concentrations at the central and southern lake sites (22 and 22B in Figs. 18-20) while they progressively increased at the northern site (22A) on the dates sampled. Copepod nauplii (juveniles) were at lower concentrations in the July and August samples compared to the September sample. Since some of the nauplii at Sunapee are too small to be collected in a 150 micron plankton net, relative concentrations of these animals might be underestimated. The smaller cladoceran herbivores *Bosmina* and *Holopedium* were generally in lower numbers.

On 3 September the cladoceran *Diaphanasoma* was at higher densities at all sites than on the previous dates. High densities of this organism is often associated with lake water containing high amounts of detritus and bacteria.

The appearance of the predominantly littoral (inshore) cladocerans *Polyphemus* and *Sida* might suggest that the tows picked up a clump of material disturbed from the shallows or lake bottom, or that detritus and bacteria were more prevalent in the lake on that date.

Concentrations of macrozooplankton had a range of 2.8 to 13.2 organisms per liter. Less than 10 organisms per liter is considered to be a low density. The range of macrozooplankton densities in lakes studied by the Freshwater Biology Group in 1986 was 0.3 (Alton Bay, Lake Winnipesaukee) to 73 (Flint Pond, Hudson) organisms per liter.

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REPORT FIGURES

Figure 1. Eutrophication of a hypothetical lake over time (years). Circled area is enlarged for comparison between short and long term trends.

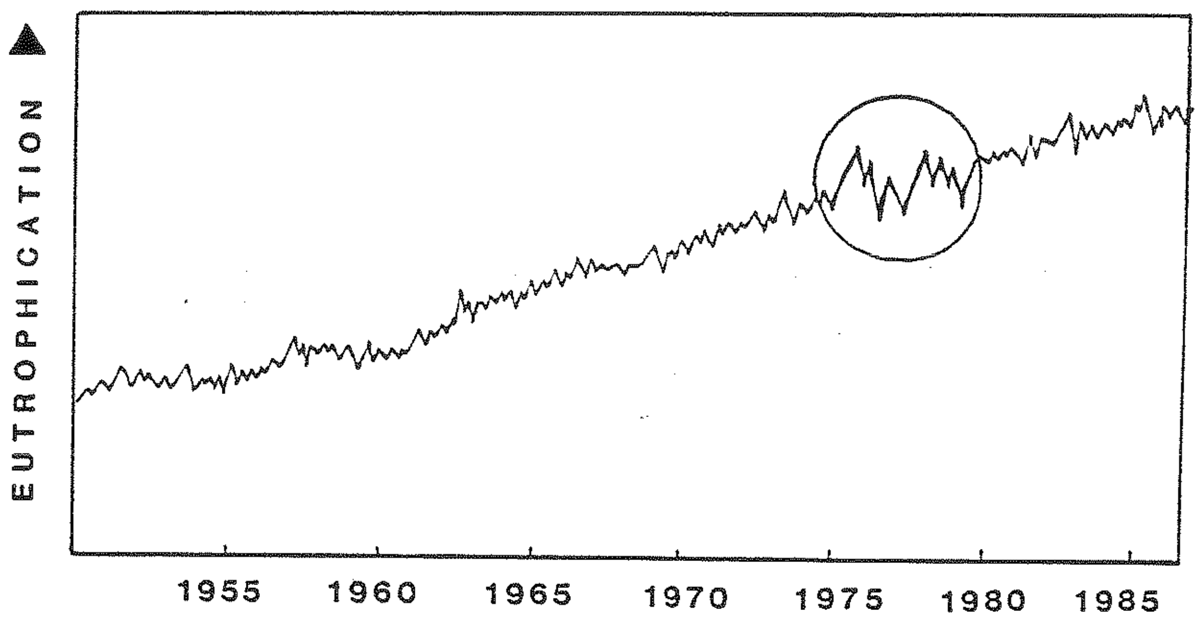
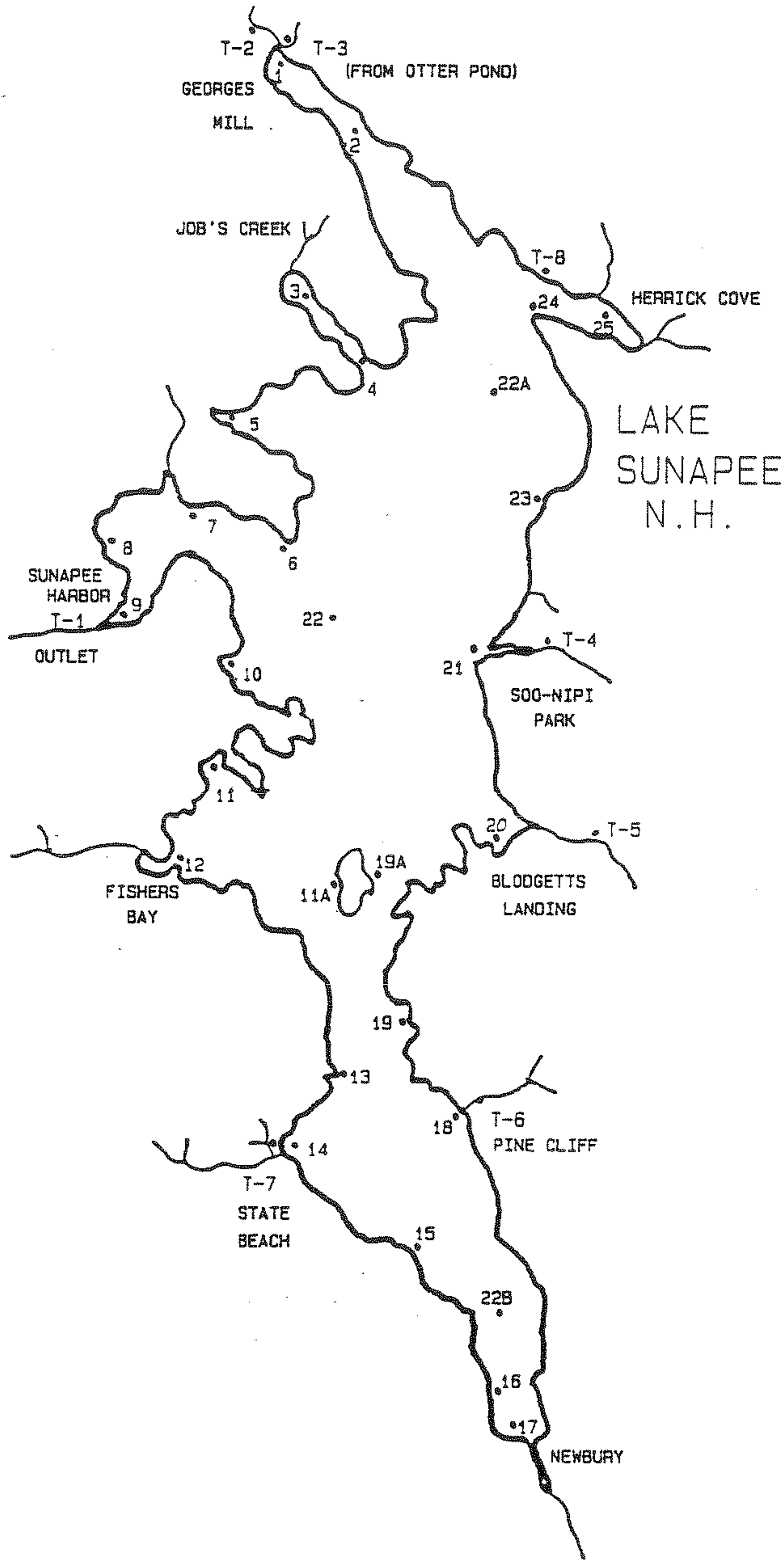

EUTROPHICATION
1955
1960
1965
1970
1975
1980
1985

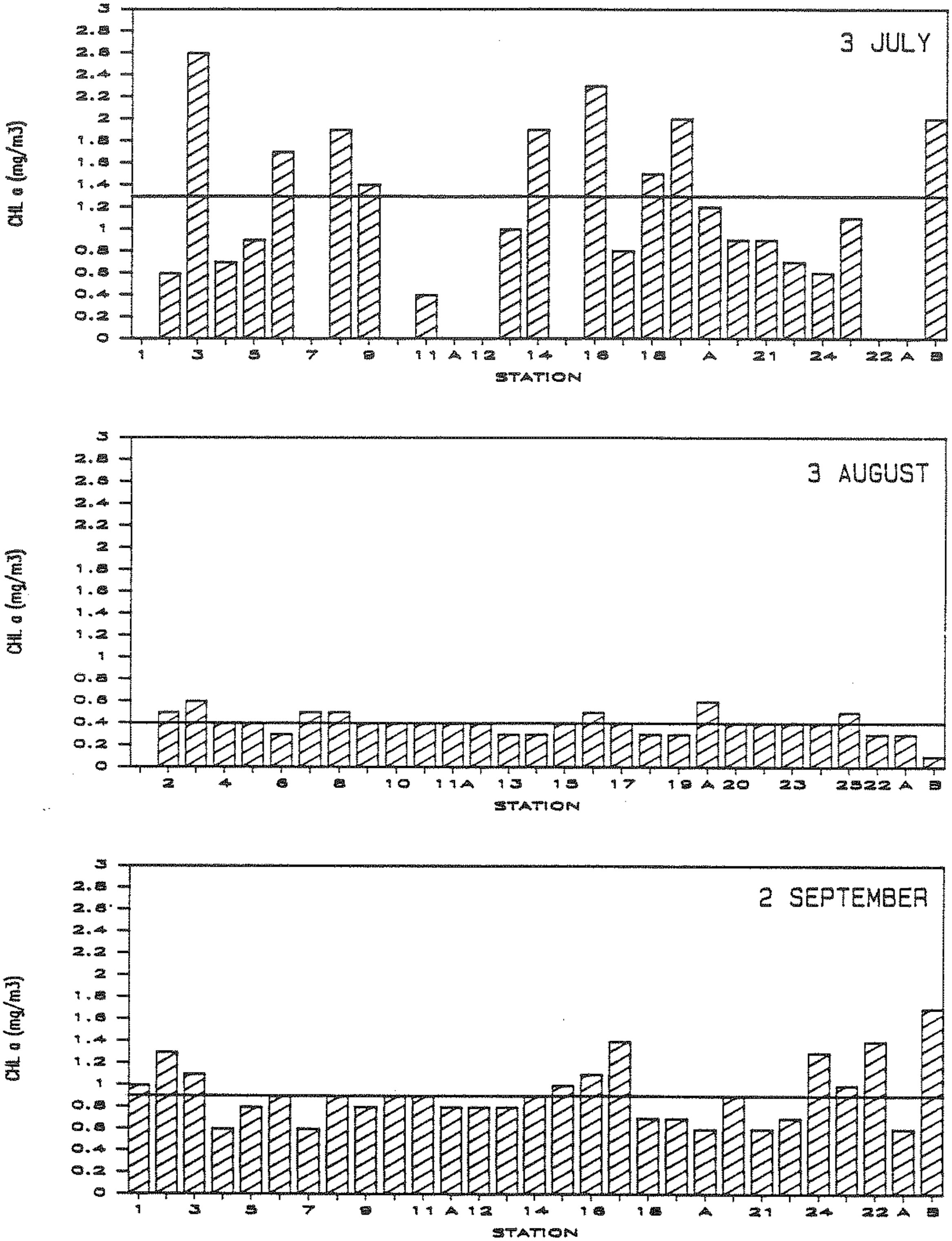
Figure 2. Location of sampling sites at Lake Sunapee, New Hampshire. Numbering is consistent with previous sampling done by Bent and Cassista.



T-2
T-3
(FROM OTTER POND)
GEORGES
MILL
1
2
JOB'S CREEK
3
T-8
24
HERRICK COVE
25
4
22A
5
LAKE
SUNAPEE
N.H.
23
7
8
6
SUNAPEE
HARBOR
9
T-1
22
OUTLET
T-4
21
10
SOO-NIPI
PARK
11
20
T-5
12
19A
FISHERS
BAY
11A
BLODGETTS
LANDING
19
13
18
T-6
PINE CLIFF
14
T-7
STATE
BEACH
15
22B
16
17
NEWBURY

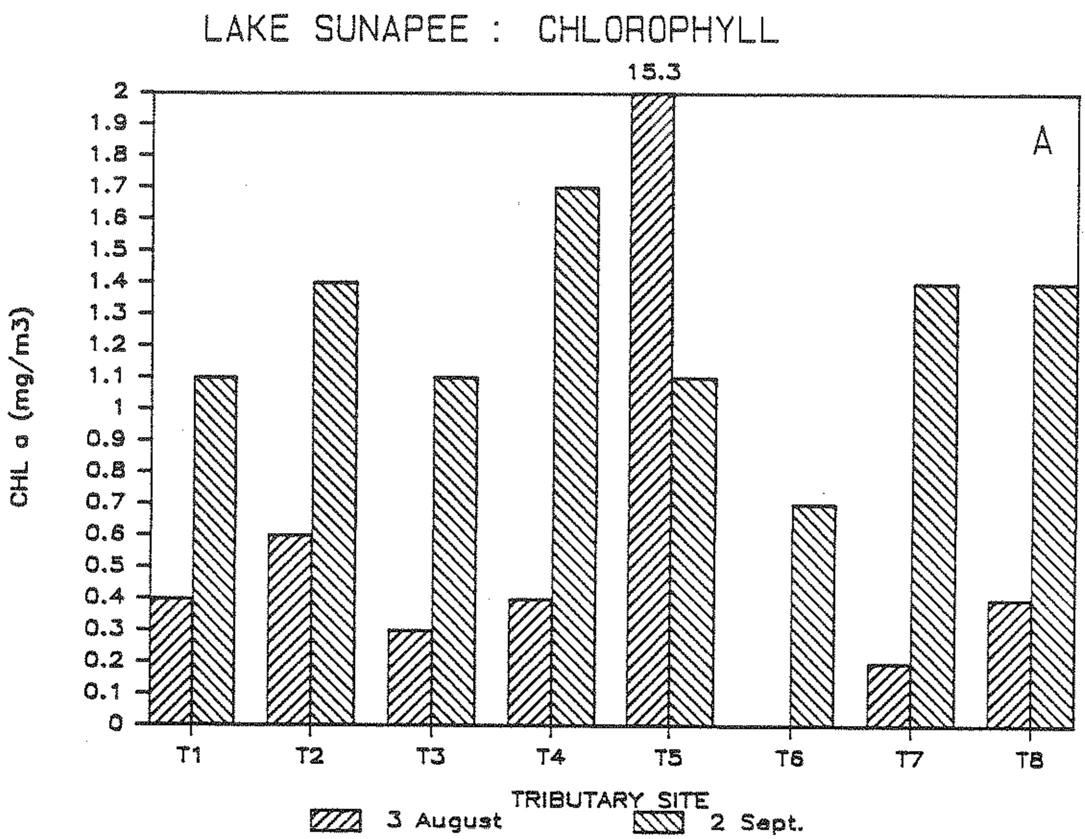
Figure 3. Lake Sunapee 1986. Concentration of Chlorophyll *a* at lake sites for 3 July (top graph), 3 August (middle graph) and 2 September (bottom graph). Sites are in order on bottom axis for shore sites 1-11, 11A, 13-19, 19A, 21, 23-25, followed by deep sites 22, 22A and 22B. Solid line indicates the lake average for that date. Concentrations are in mg per m3 of chlorophyll *a*.

CHLOROPHYLL a



LAKE SUNAPEE 1986

Figure 4. Lake Sunapee 1986. A- Concentration of Chlorophyll *a* at the outlet (T-1) and tributaries (T2 to T8) on 3 August (bar above-left of site number) and 2 September (bar above-right of site number). Note that T-5 concentration is off of the scale (15.3 mg -3). Concentrations are in mg per m3. B- Concentration of Dissolved Color. Sites and dates are as described for A above. Concentrations are in platinate color units (ptu).


LAKE SUNAPEE : CHLOROPHYLL
15.3
A
CHL a (mg/m3)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
T1
T2
T3
T4
T5
T6
T7
T8
TRIBUTARY SITE
3 August
2 Sept.

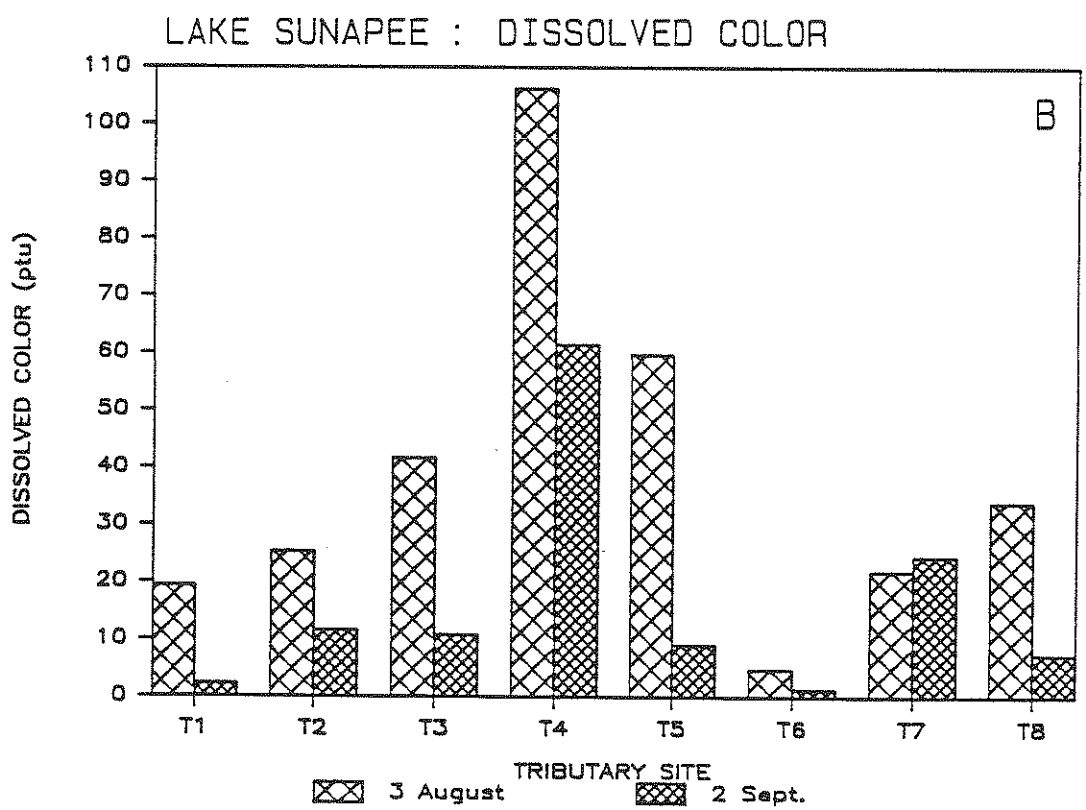
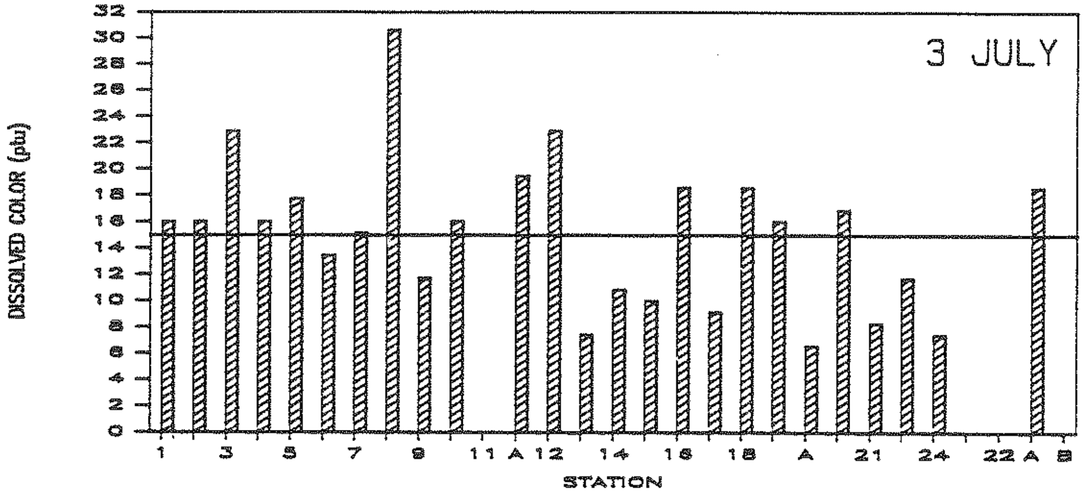
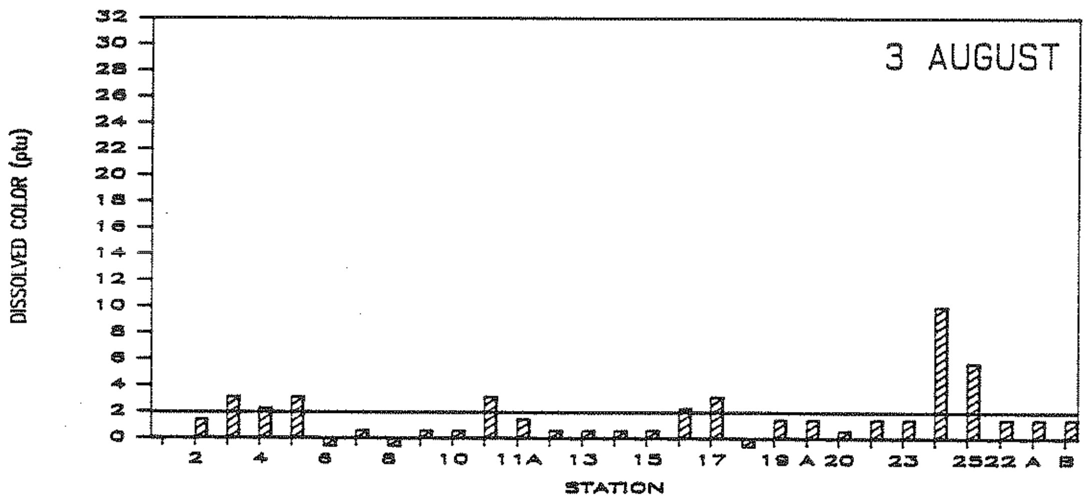

LAKE SUNAPEE : DISSOLVED COLOR
B
DISSOLVED COLOR (ptu)
110
100
90
80
70
60
50
40
30
20
10
0
T1
T2
T3
T4
T5
T6
T7
T8
TRIBUTARY SITE
3 August
2 Sept.

Figure 5. Lake Sunapee 1986. Concentration of dissolved color at lake sites for 3 July (top graph), 3 August (middle graph) and 2 September (bottom graph). Sites are in order on bottom axis for shore sites 1-11, 11A, 13-19, 19A, 21, 23-25, followed by deep sites 22, 22A and 22B. Solid line indicates the lake average for that date. Concentrations are in platinate color color units (ptu).

DISSOLVED COLOR





LAKE SUNAPEE 1986

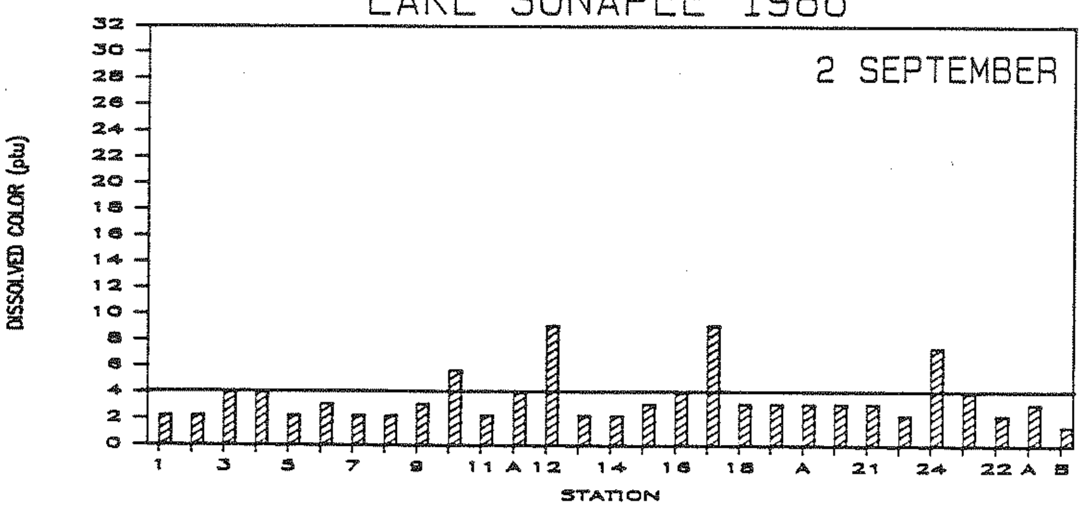


Figure 6. Lake Sunapee 1986. Concentration of Total Phosphorus at lake sites for 3 July (top graph), 3 August (middle graph) and 2 September (bottom graph). Sites are in order on bottom axis for shore sites 1-11, 11A, 13-19, 19A, 21, 23-25, followed by deep sites 22, 22A and 22B. Solid line indicates the lake average for that date. Concentrations are in parts per billion which is equivalent to micrograms per liter.

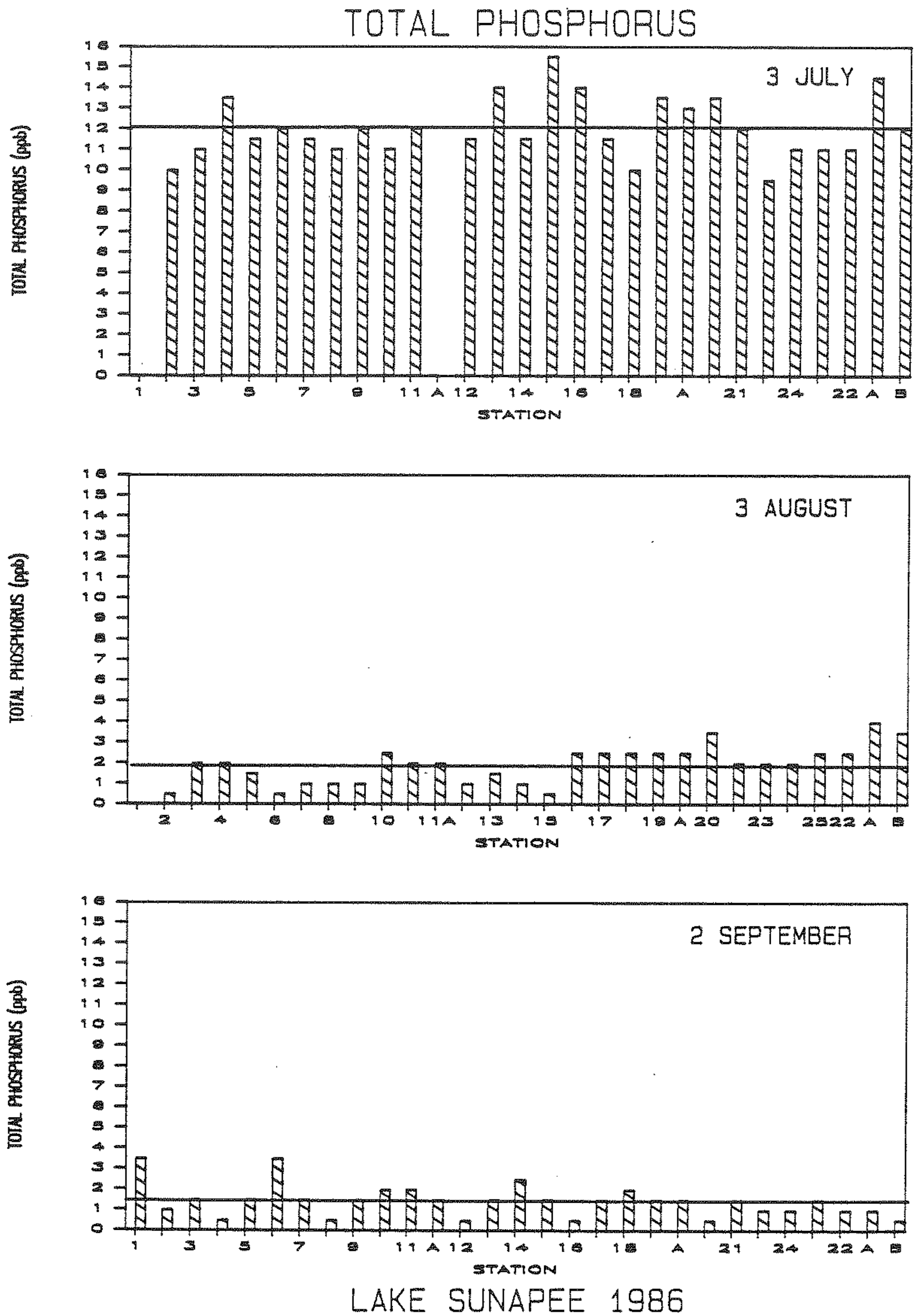
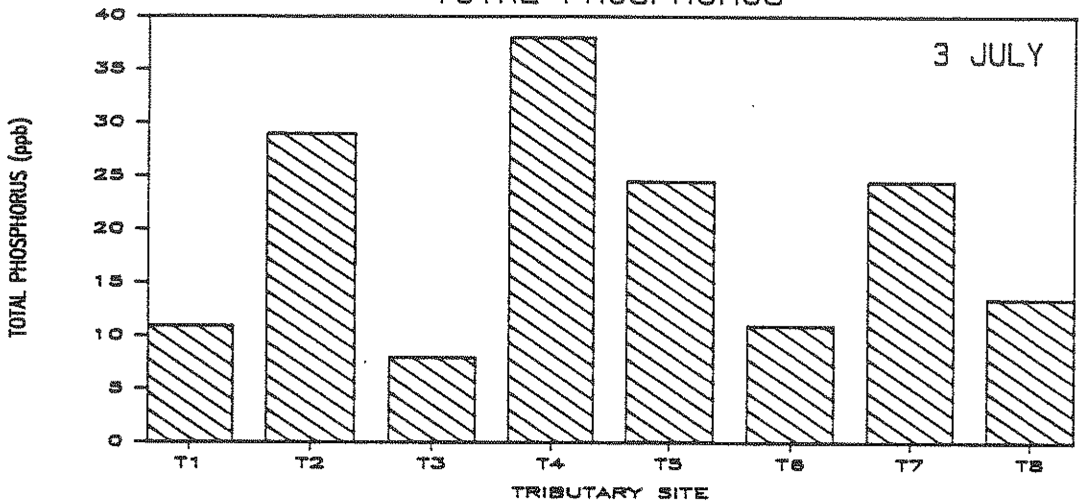
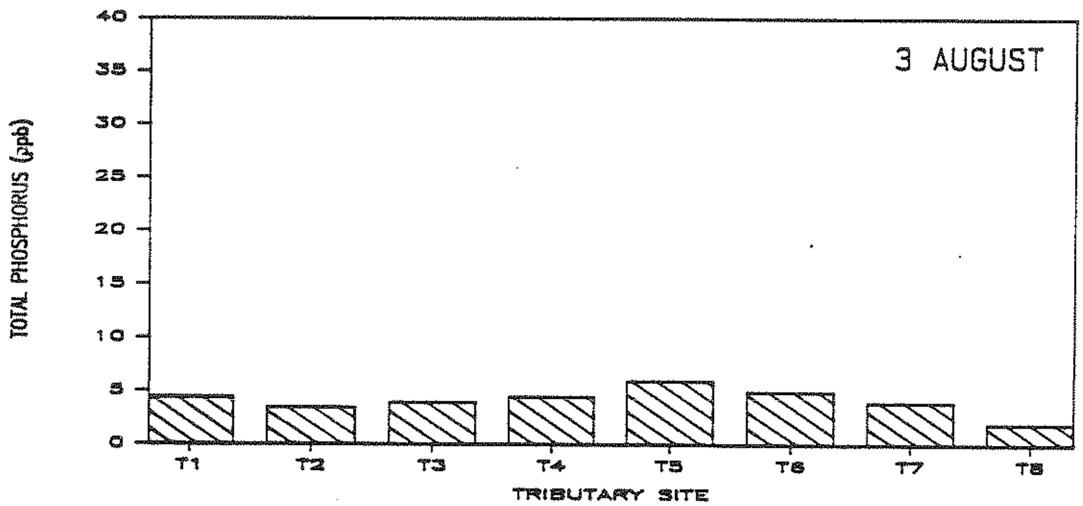

TOTAL PHOSPHORUS
3 JULY
3 AUGUST
2 SEPTEMBER
TOTAL PHOSPHORUS (ppb)
STATION
LAKE SUNAPEE 1986

Figure 7. Lake Sunapee 1986. Concentration of Total Phosphorus at outlet (T-1) and tributary sites (T-2 to T-8) for 3 July (top graph), 3 August (middle graph) and 2 September (bottom graph). Concentrations are in parts per billion which is equivalent to micrograms per liter.

LAKE SUNAPEE 1986

TOTAL PHOSPHORUS





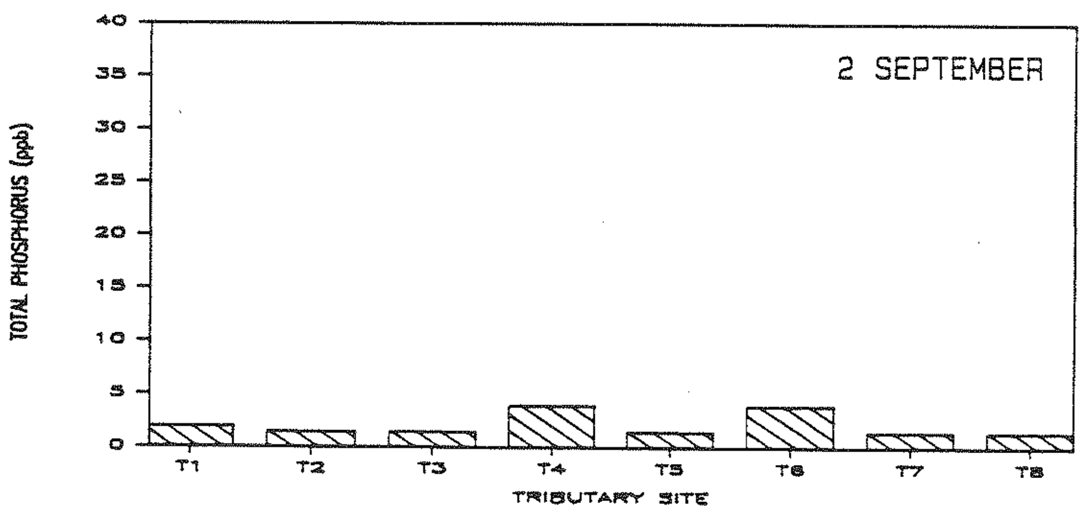
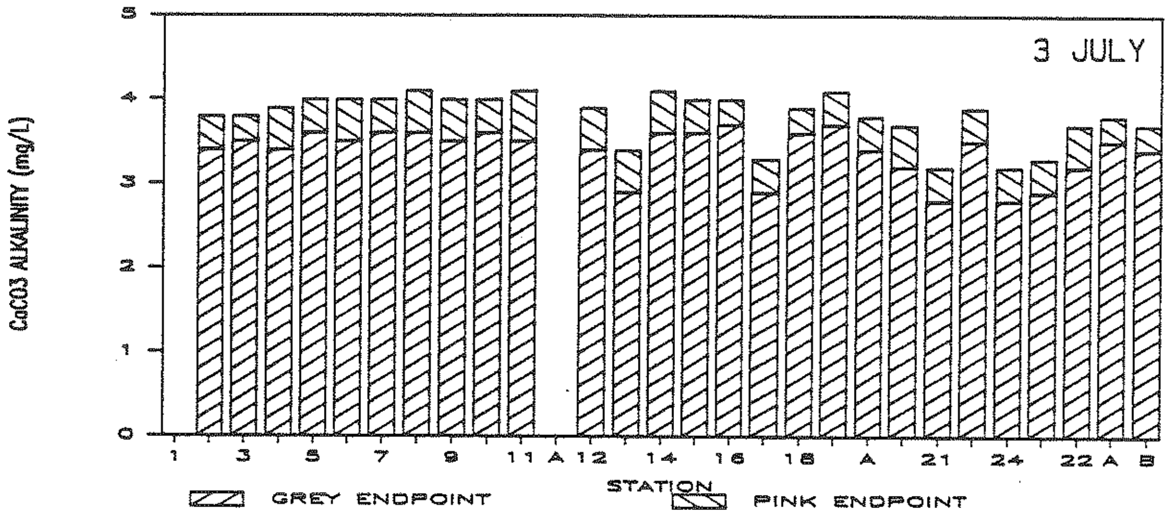
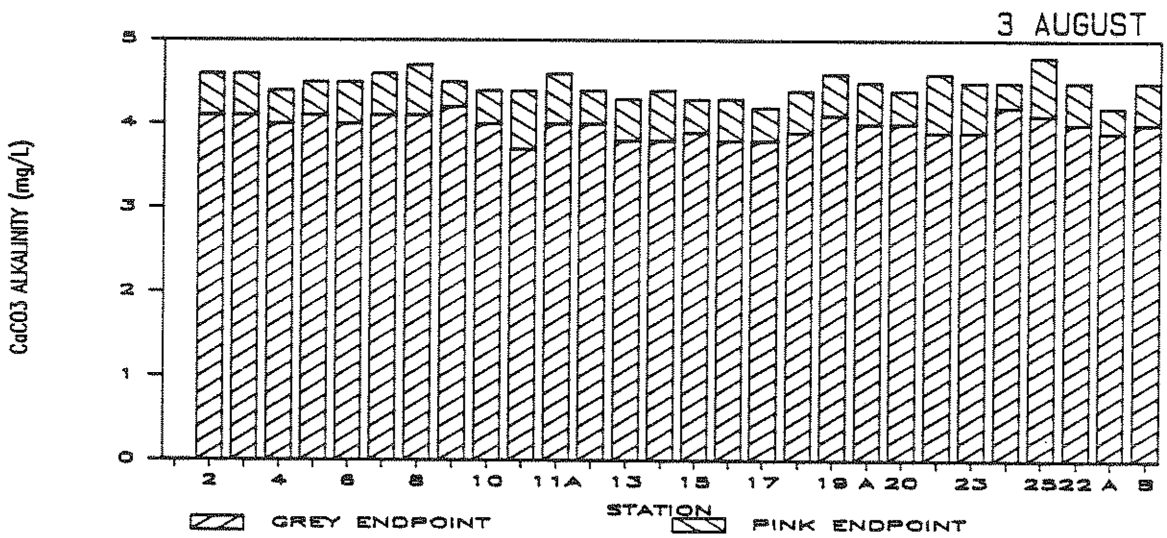


Figure 8. Lake Sunapee 1986. Total Alkalinity at lake sites for 3 July (top graph), 3 August (middle graph) and 2 September (bottom graph). Sites are in order on bottom axis for shore sites 1-11, 11A, 13-19, 19A, 21, 23-25, followed by deep sites 22, 22A and 22B. Height of bottom bar represents grey endpoint, height of both bars together represents pink endpoint (see text "Methods of the FBG" and "Alkalinity" in "Results and Discussion" for explanation of endpoints). Concentrations are in mg per liter total alkalinity as Calcium Carbonate.

LAKE SUNAPEE 1986
TOTAL ALKALINITY





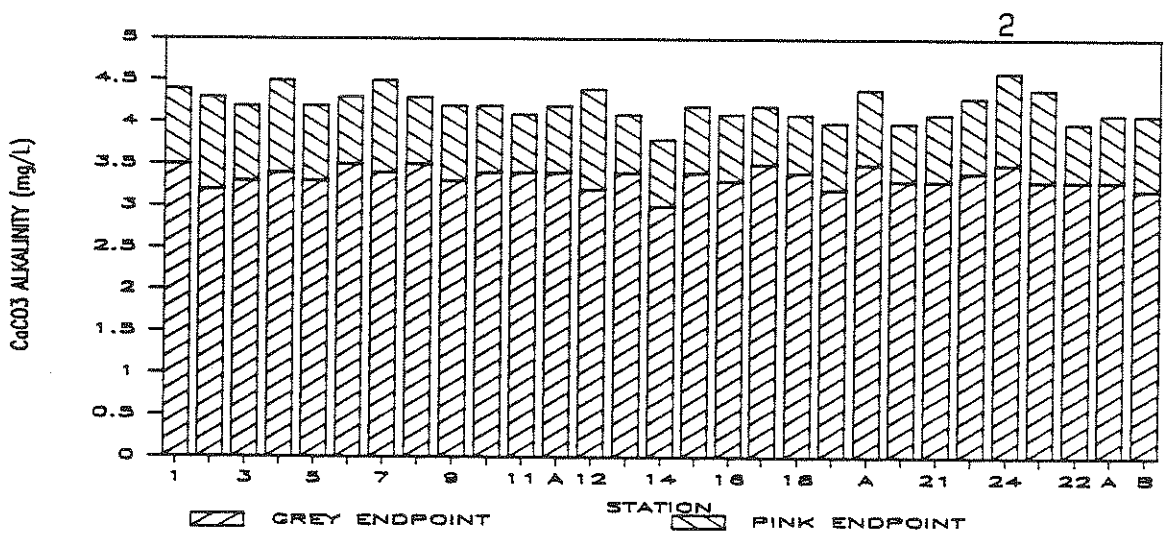


Figure 9. Lake Sunapee 1986. Total Alkalinity at the outlet (T-1) and tributary sites (T-2 to T-8) for 3 July (top graph), 3 August (middle graph) and 2 September (bottom graph). Height of bottom bar represents grey endpoint, height of both bars together represents pink endpoint (see text "Methods of the FBG" and "Alkalinity" in "Results and Discussion" for explanation of endpoints). Concentrations are in mg per liter alkalinity as Calcium Carbonate.

LAKE SUNAPEE 1986
TOTAL ALKALINITY

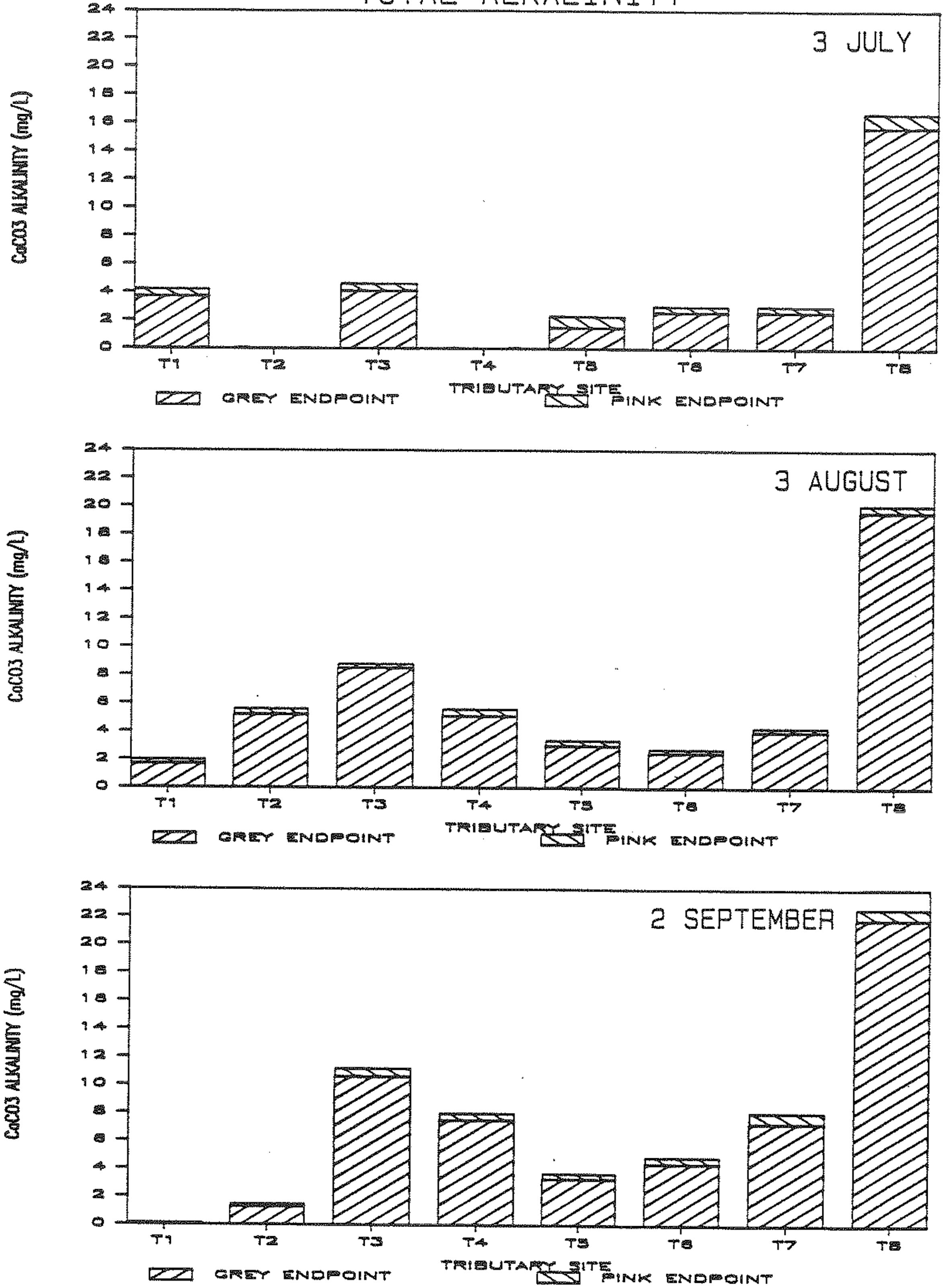
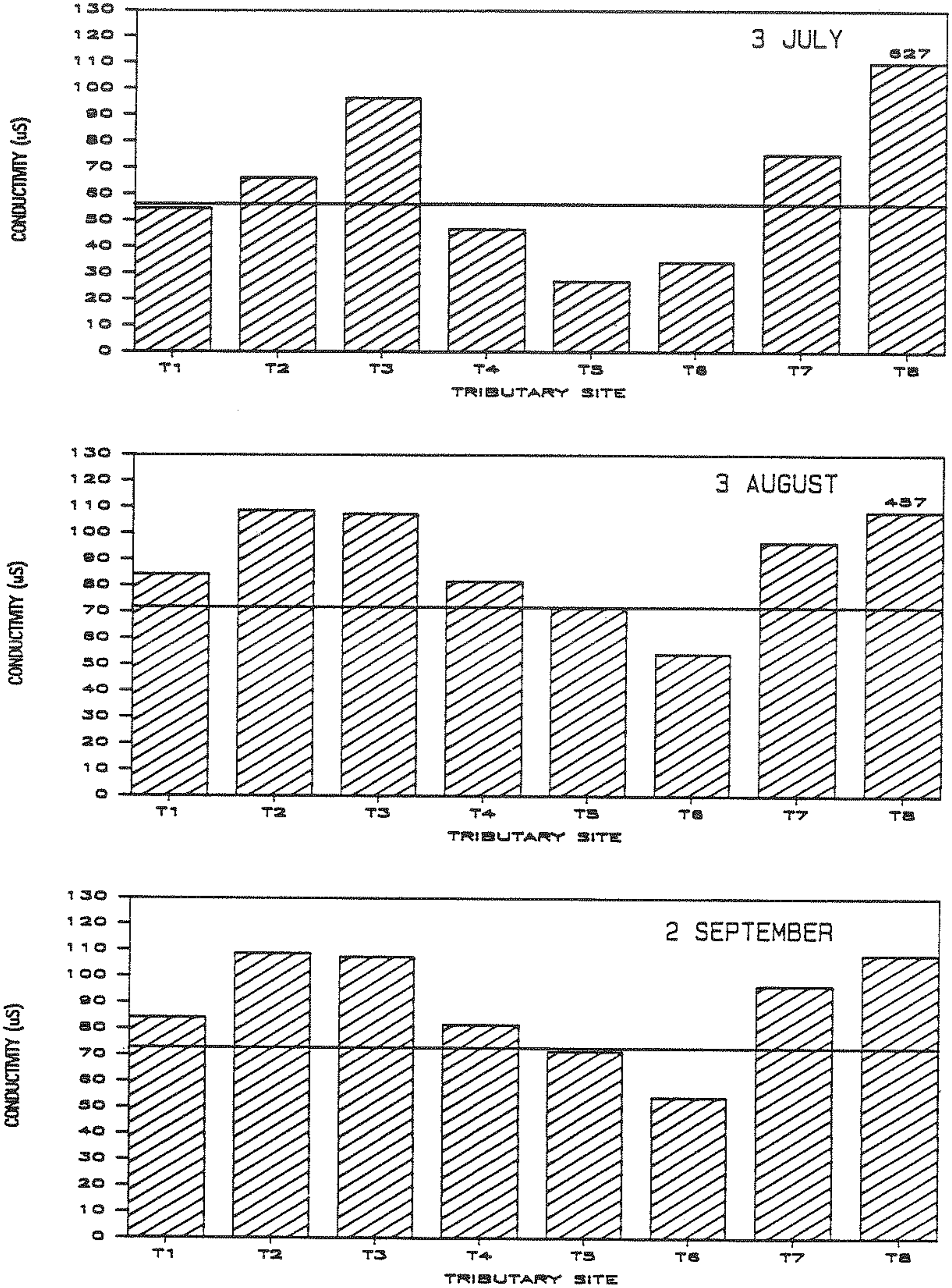


Figure 10. Lake Sunapee 1986. Specific Conductivity (18oC) at the outlet (T-1) and tributary sites (T-2 to T-8) for 3 July (top graph), 3 August (middle graph) and 2 September (bottom graph). Note that T-8 had values off scale on 3 July (627 uS) and 3 August (457 uS). Solid line indicates the lake average for that date. Units are in micro-Siemens (uS) which are equivalent to micro-mhos per cm2.

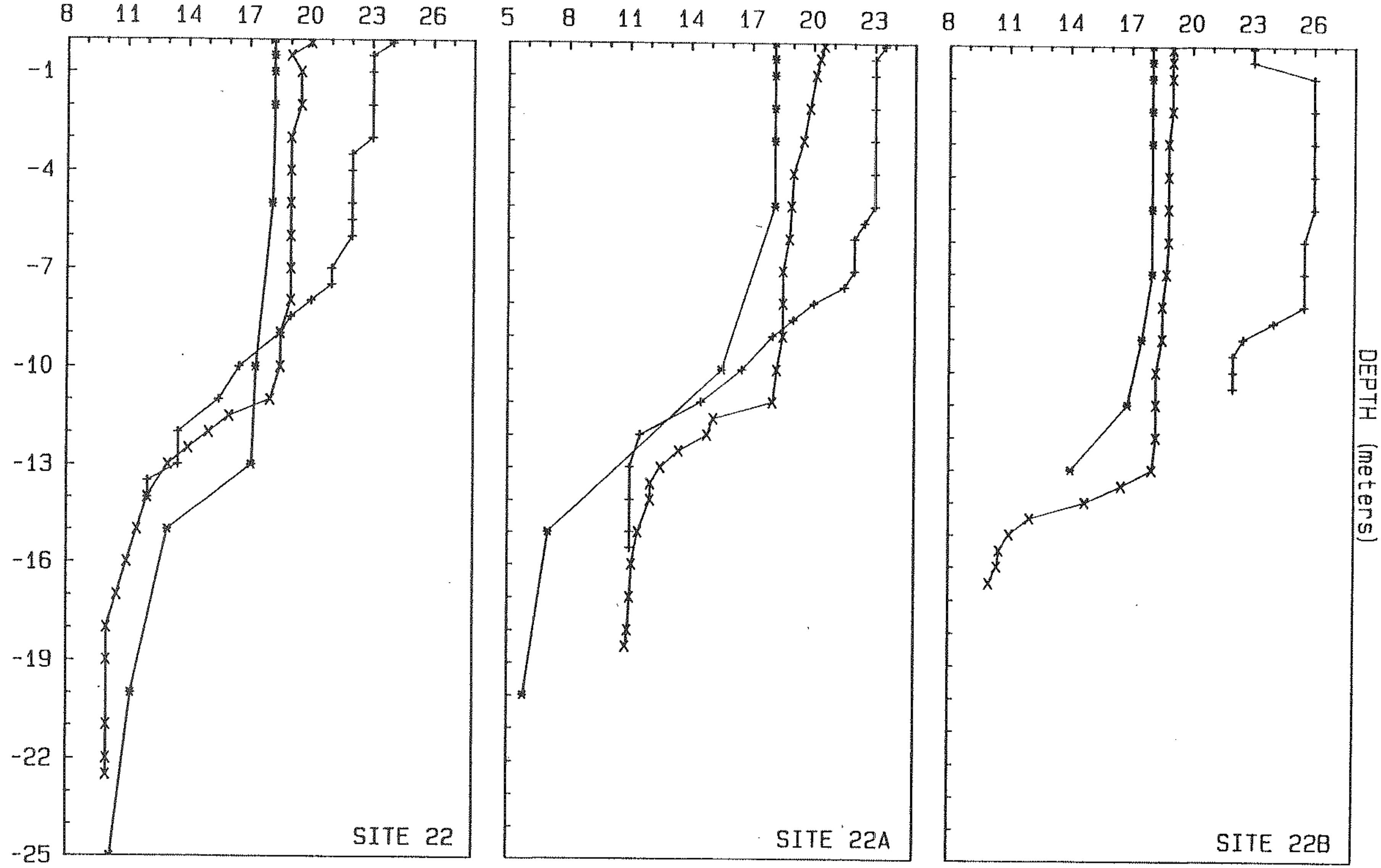
SPECIFIC CONDUCTIVITY



LAKE SUNAPEE 1986

Figure 11. Lake Sunapee 1986. Profiles of temperature degrees Centigrade (horizontal axis) versus depth in meters (vertical axis with the lake surface at the top of the graph) for lake deep sites 22 (left graph), 22A (center graph) and 22B (right graph) on 3 July (asterisks), 3 August (crosses) and 2 September (x's).

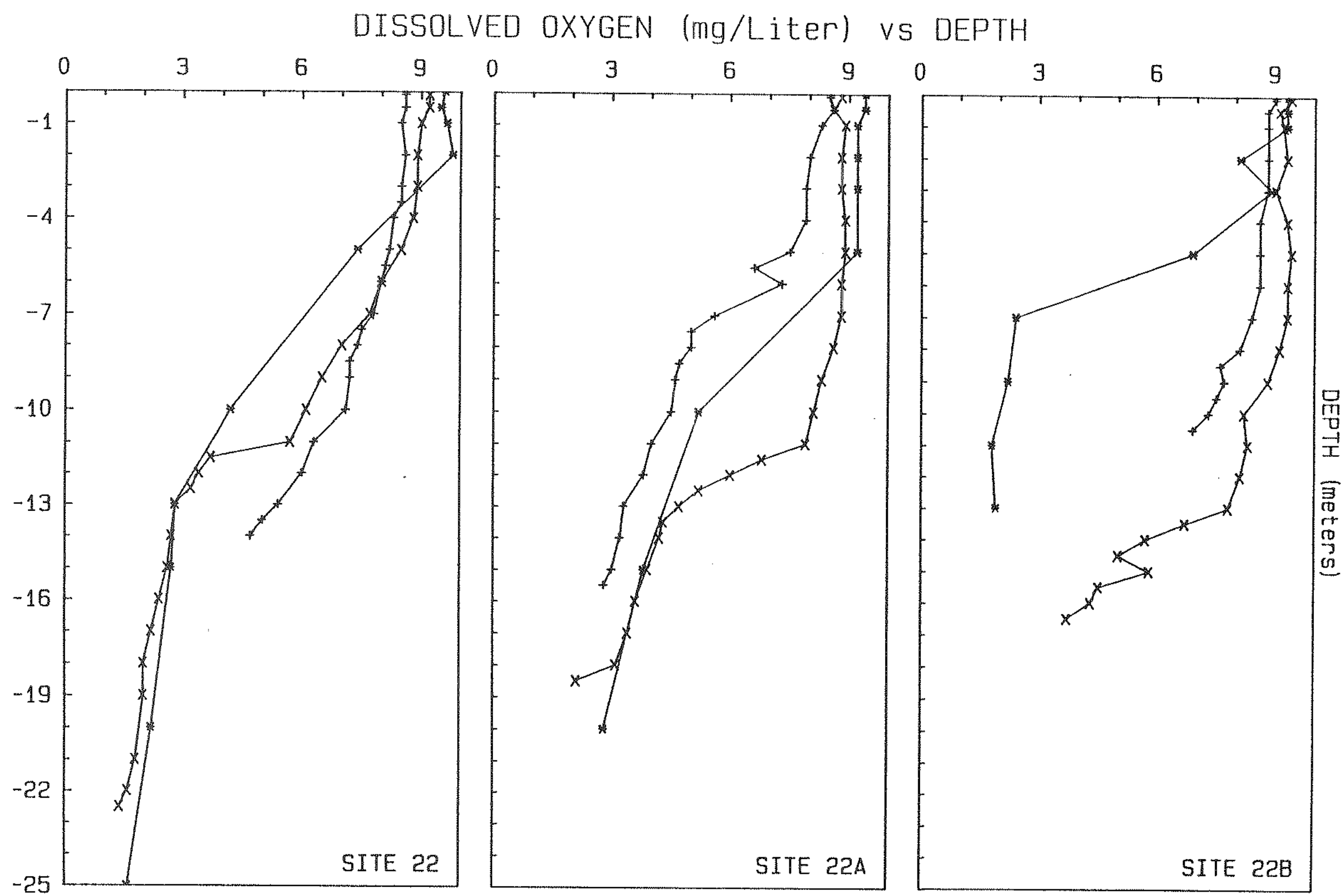
TEMPERATURE - DEPTH PROFILES (°C)



Lake Sunapee Deep Water Stations 1986

- 3 July +-+ 3 August X-X 2 Sept.

Figure 12. Lake Sunapee 1986. Profiles of Dissolved Oxygen in milligrams per liter (parts per million) (horizontal axis) versus depth in meters (vertical axis with the lake surface at the top of the graph) for lake deep sites 22 (left graph), 22A (center graph) and 22B (right graph) on 3 July (asterisks), 3 August (crosses) and 2 September (x's)

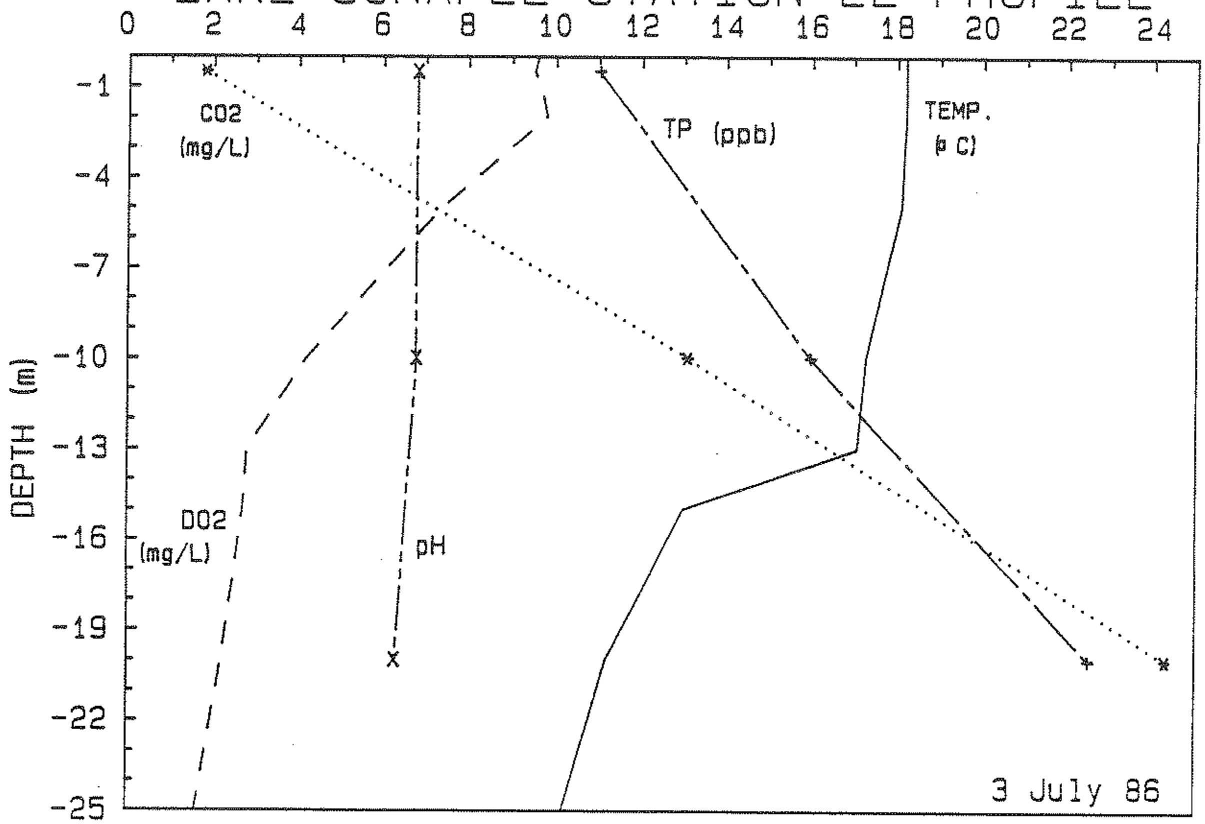


Lake Sunapee Deep Stations 1986

- 3 July +-+ 3 August X-X 2 Sept.

Figure 13. Lake Sunapee 1986. Site 22 (central deep site) comparison of Temperature (Temp), Dissolved Oxygen (DO2), "Free Carbon Dioxide" (CO2), Total Phosphorus (TP), and pH on 3 July (top graph) and 2 August (bottom graph). Units are as labeled. Dissolved oxygen and temperature were measured every 0.5 meters. Carbon dioxide, phosphorus and pH were measured at specific depths (0.5, 10 and 20 m on 3 July and 0.5, 6.0, 12 and 16 m on 2 August.

LAKE SUNAPEE STATION 22 PROFILE



DO2 = DISSOLVED OXYGEN CO2 = CARBON DIOXIDE TP = TOTAL PHOSPHORUS

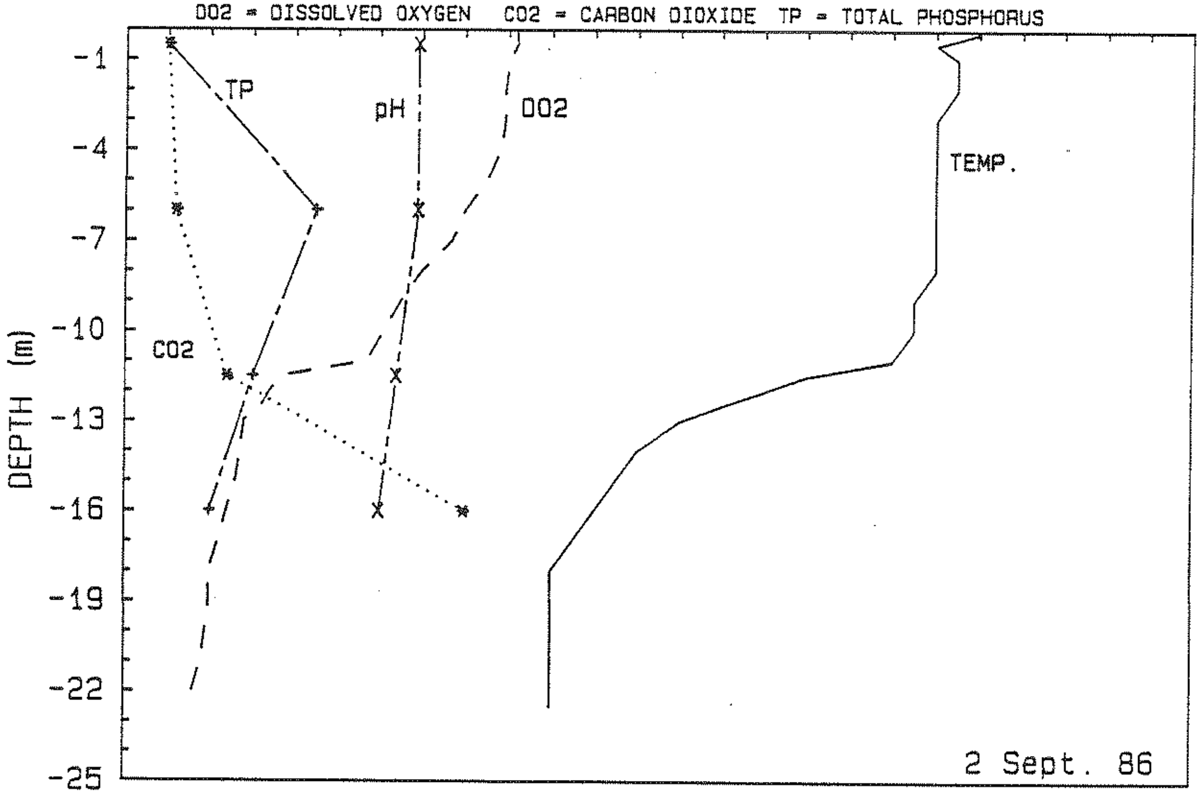
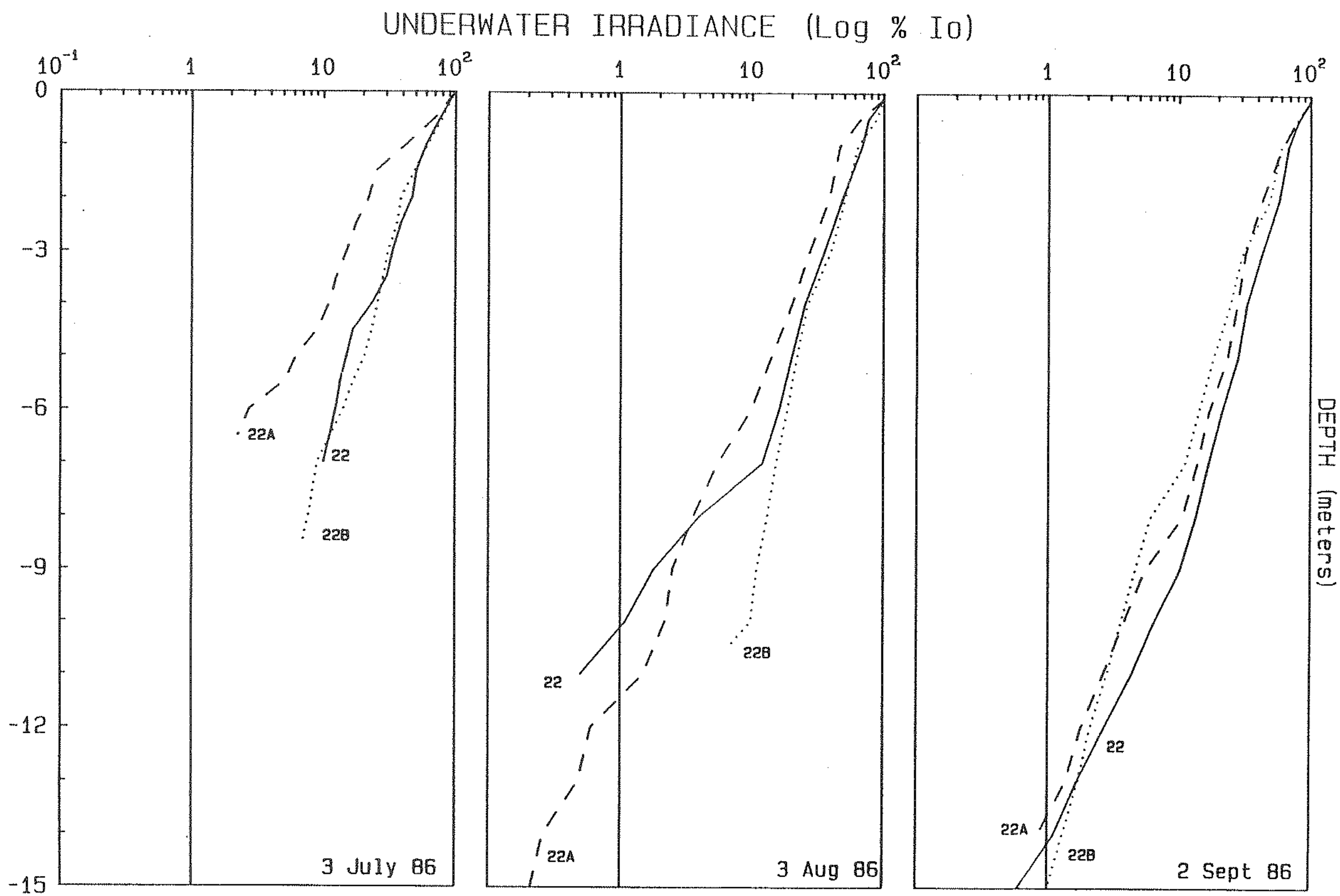


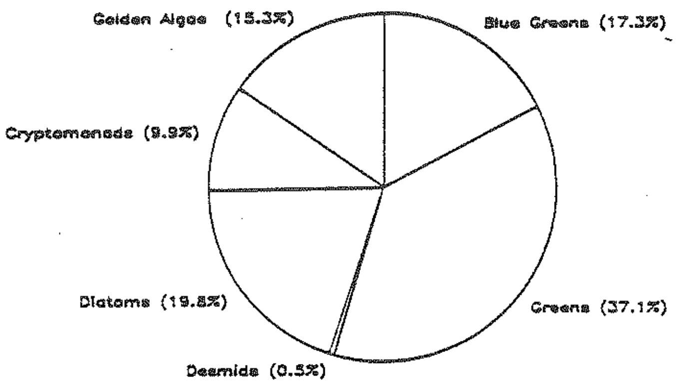
Figure 14. Lake Sunapee 1986. Profiles of underwater irradiance (horizontal axis) versus depth (vertical axis with the lake surface at the top of the graph) for lake deep sites 22 (solid lines), 22A (dashed lines) and 22B (dotted lines) on 3 July (left graph), 3 August (center graph) and 2 September (right graph) . Units of irradiance are expressed as percent relative to the surface irradiation (Io)and the scale is logarithmic (base 10). Solid vertical line marks the 1 percent light level or "compensation point". Where the irradiance plots intersect the vertical line may be considered the bottom of the photic zone (see text for further discussion).



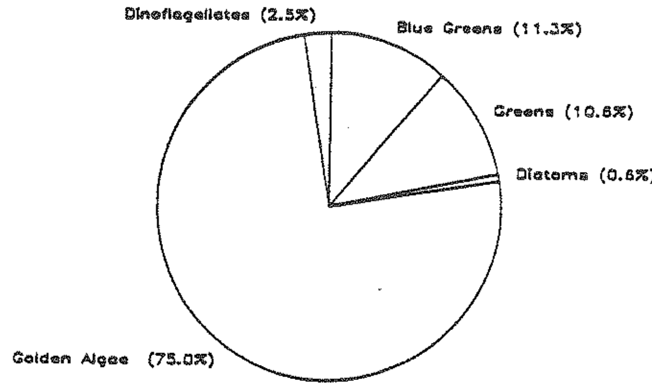
Lake Sunapee Deep Water Stations

Figure 15. Lake Sunapee 1986. Relative percent by algal group (pie diagrams) for various dates, and phytoplankton densities for all dates sampled (bar graph) for deep site 22 . Pie diagrams (from top-left down) are 3 July, 2 meters; 3 August, 0-6 meters integrated; (top-right down) 2 September, 0.5 meters; 2 September, 12 meters; 2 September, 22 meters. Bar graph is thousands of organisms per milliliter for each date/depth sampled.

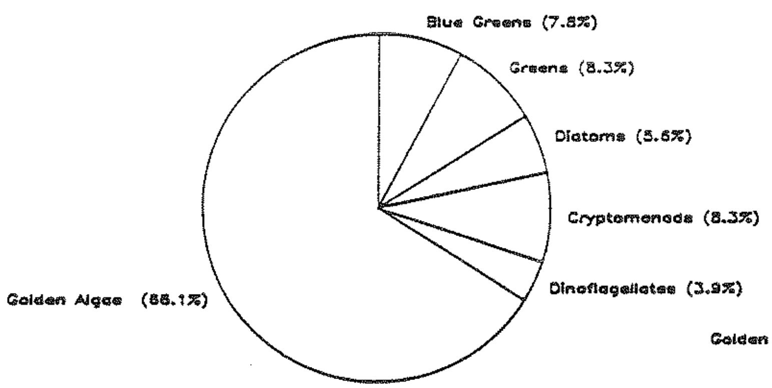
Site 22 7/3/86



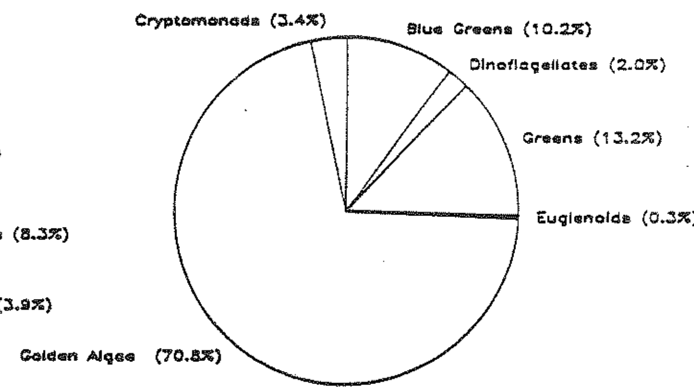
Site 22 0.5m 9/2/86

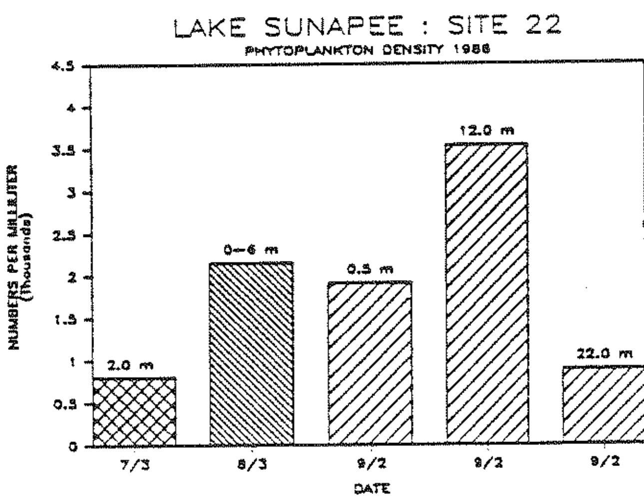


Site 22 8/3/86



Site 22 12.0m 9/2/86





Site 22 22m 9/2/86

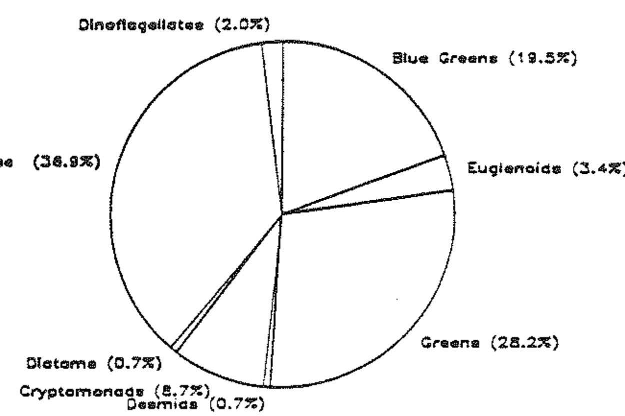
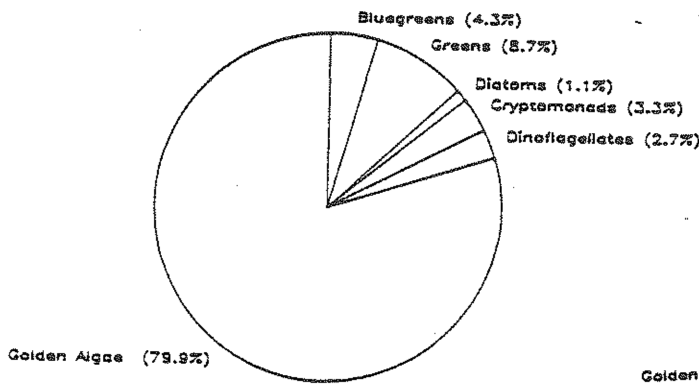
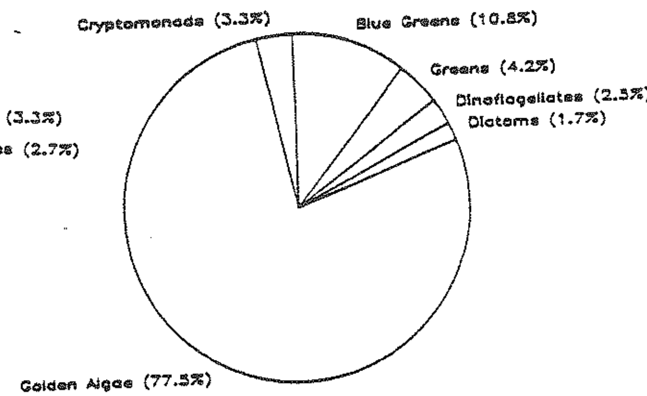


Figure 16. Lake Sunapee 1986. Relative percent by algal group (pie diagrams) for various dates, and phytoplankton densities for all dates sampled (bar graph) for deep site 22A. Pie diagrams (from top-left down) are 3 July, 0.5 meters; 3 July, 10 meters; (top-right down) 2 September, 6.0 meters; 2 September, 11.5 meters; 2 September, 15 meters. Bar graph is thousands of organisms per milliliter for each date/depth sampled.

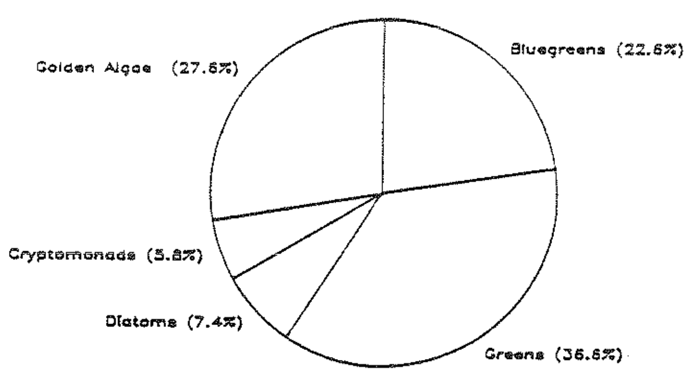
22A 0.5 7/3/86



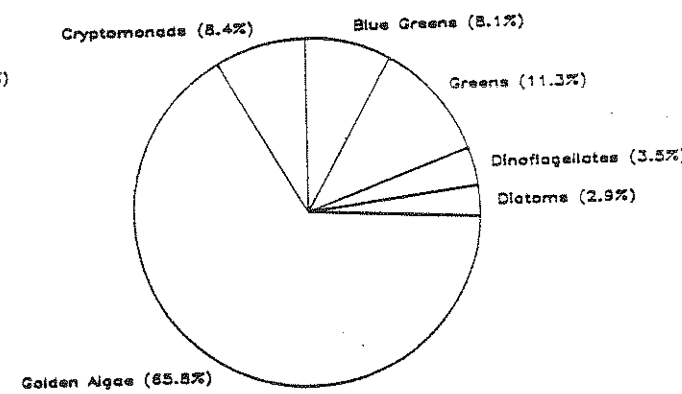
STA22A 6m 860902

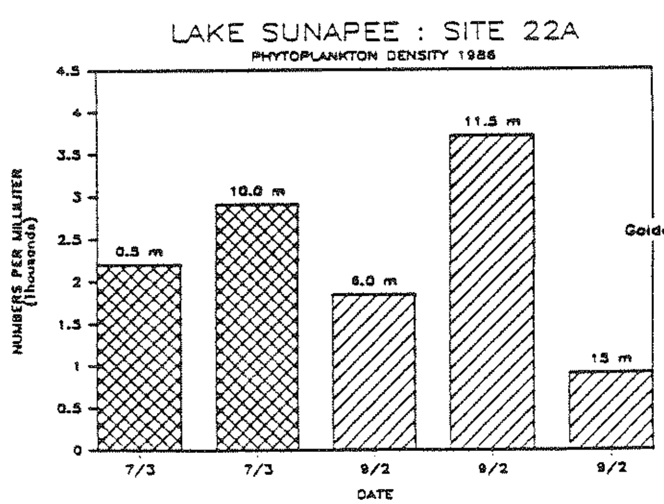


22A 10.0m 7/3/86



STA22A 11.5m 860902





STA22A 15.0m 860902

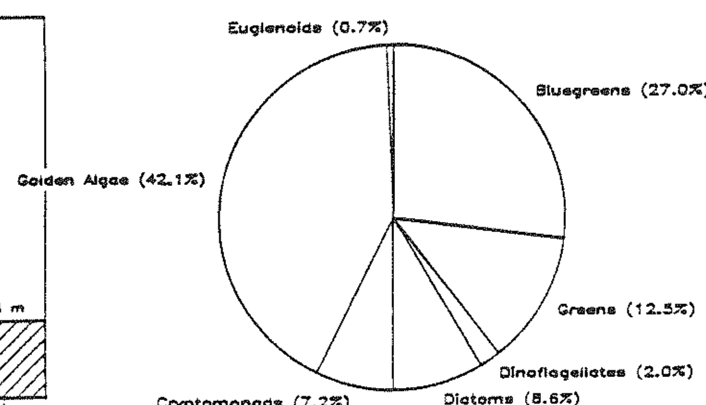
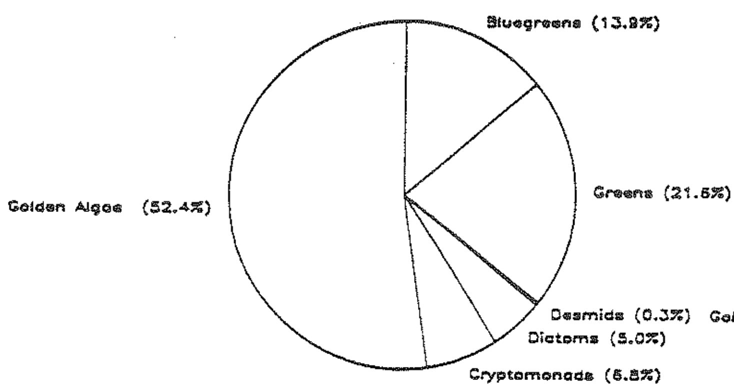
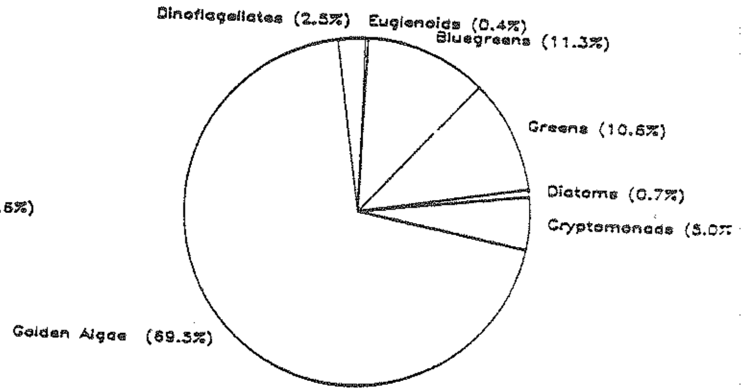


Figure 17. Lake Sunapee 1986. Relative percent by algal group (pie diagrams) for various dates, and phytoplankton densities for all dates sampled (bar graph) for deep site 22B. Pie diagrams (from top-left down) are 3 July, 2.0 meters; 3 July, 8.0 meters; (top-right down) 2 September, 6.0 meters; 2 September 14 meters; 2 September, 16 meters. Bar graph is thousands of organisms per milliliter for each date/depth sampled.

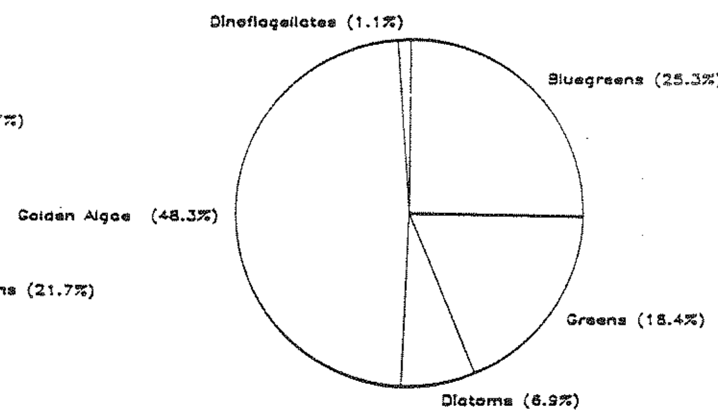
22B 2m 7/3/86



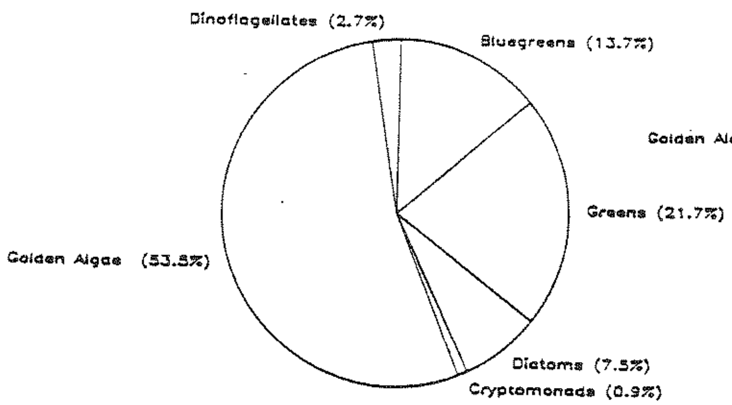
22B 6m 9/2/86

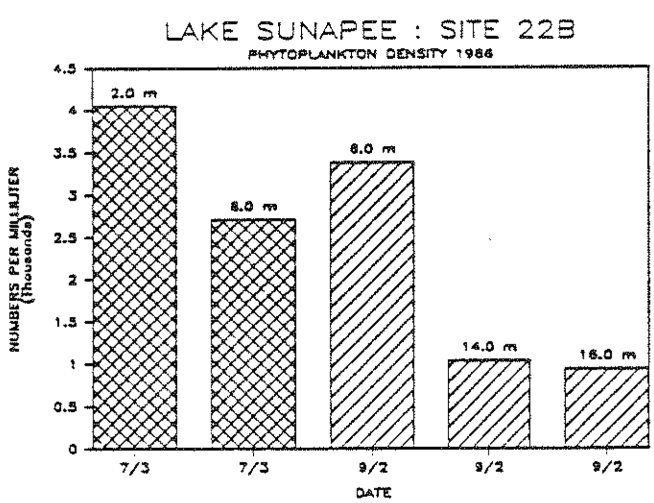


22B 14m 9/2/86



22B 8m 7/3/86





22B 16m 9/2/86

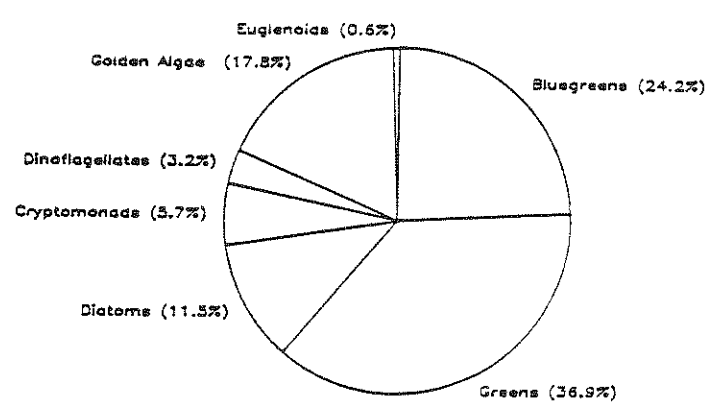
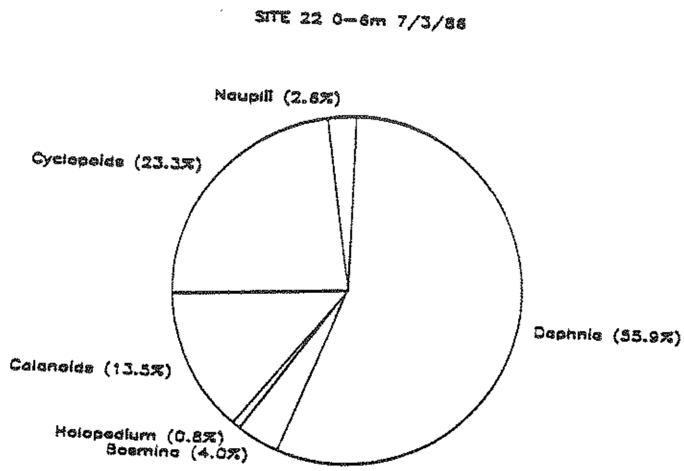
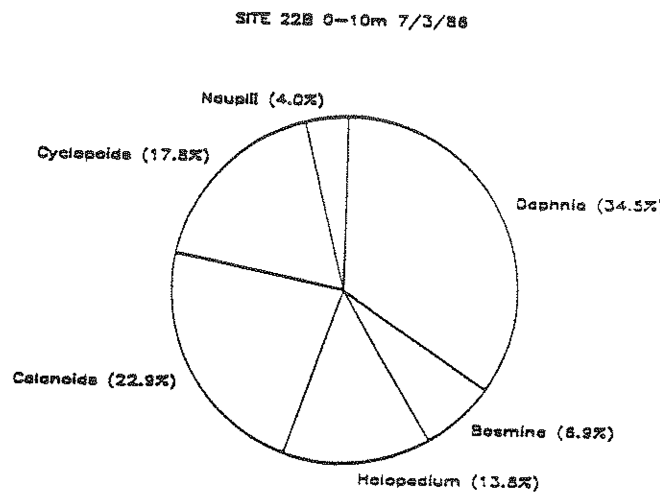


Figure 18. Lake Sunapee 1986. Relative percent by macrozooplankton group (pie diagrams) for each deep site, and macrozooplankton densities for all deep sites sampled (bar graph) on 3 July. Pie diagrams (left to right) are 3 July, 0-6 meters tow, site 22; and 3 July, 0-10 meters tow, site 22B. Height of bar is number of organisms per liter for each date/depth of tow combination sampled. Each subsection of the bar represents numbers of small herbivores, large herbivores and carnivores as indicated (from bottom to top respectively). Macrozooplankton counted were those that could be captured in a 150 micrometer mesh-size plankton net.


SITE 22 0—6m 7/3/86
Naupili (2.6%)
Cyclopoids (23.3%)
Daphnia (55.9%)
Calanoids (13.5%)
Holopedium (0.8%)
Bosmina (4.0%)


SITE 22B 0—10m 7/3/86
Naupili (4.0%)
Cyclopoids (17.8%)
Daphnia (34.5%)
Calanoids (22.9%)
Bosmina (6.9%)
Holopedium (13.8%)

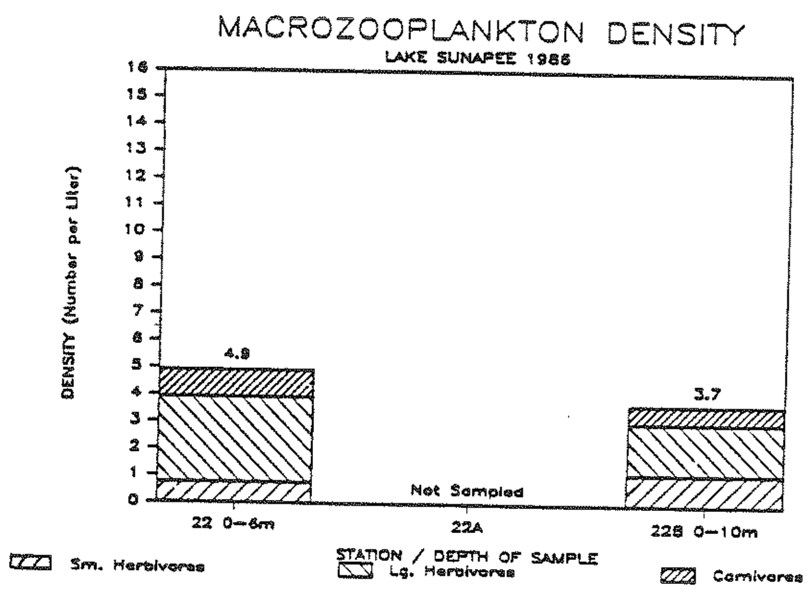
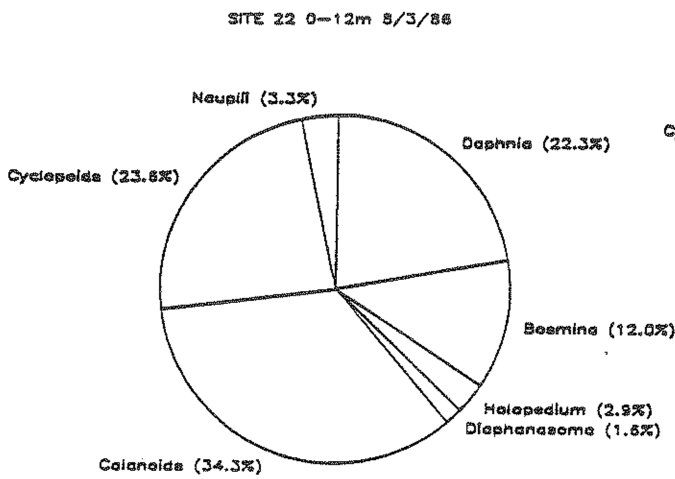
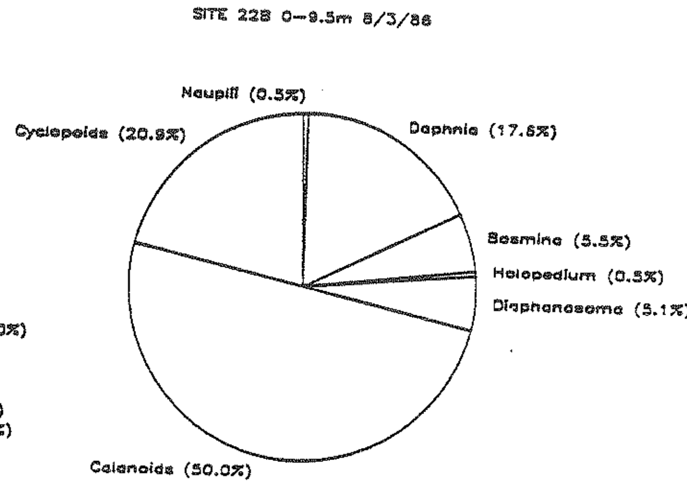
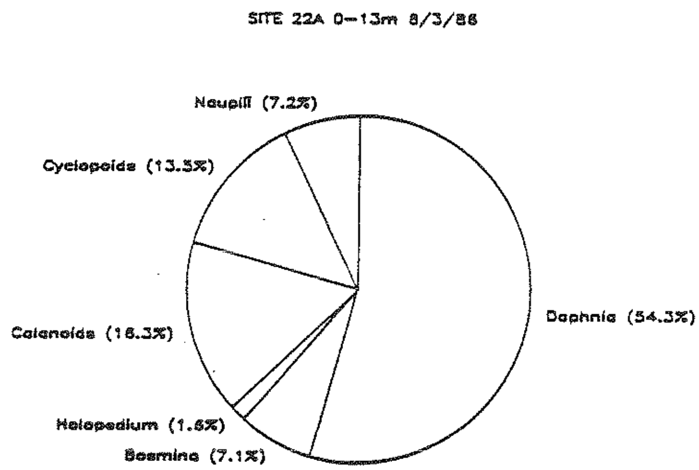

MACROZOOPLANKTON DENSITY
LAKE SUNAPEE 1986
DENSITY (Number per Liter)
4.9
3.7
Not Sampled
22 0—6m
22A
22B 0—10m
STATION / DEPTH OF SAMPLE
Sm. Herbivores
Lg. Herbivores
Carnivores

Figure 19. Lake Sunapee 1986. Relative percent by macrozooplankton group (pie diagrams) for each deep site, and macrozooplankton densities for all deep sites sampled (bar graph) on 3 August . Pie diagrams (counter-clockwise from top-left) are 3 August, 0-12 meters tow, site 22; 3 August, 0-13 meters tow, site 22A and 3 August, 0-9.5 meters tow, site 22B. Total height of bar is number of organisms per liter for each date/depth of tow combination sampled. Each subsection of the bar represents numbers of small herbivores, large herbivores and carnivores as indicated (from bottom to top respectively). Macrozooplankton counted were those that could be captured in a 150 micrometer mesh-size plankton net.


SITE 22 0-12m 8/3/86
Nauplii (3.3%)
Daphnia (22.3%)
Cyclopoids (23.6%)
Bosmina (12.0%)
Holopedium (2.9%)
Diaphanosoma (1.6%)
Calanoids (34.3%)


SITE 22B 0-9.5m 8/3/86
Nauplii (0.5%)
Cyclopoids (20.9%)
Daphnia (17.6%)
Bosmina (5.5%)
Holopedium (0.5%)
Diaphanosoma (5.1%)
Calanoids (50.0%)


SITE 22A 0-13m 8/3/86
Nauplii (7.2%)
Cyclopoids (13.3%)
Calanoids (16.3%)
Daphnia (54.3%)
Holopedium (1.6%)
Bosmina (7.1%)

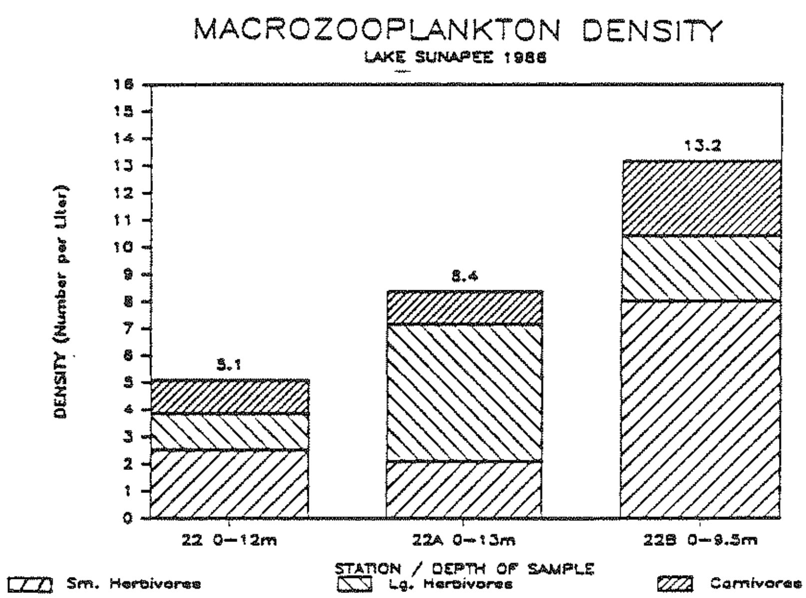
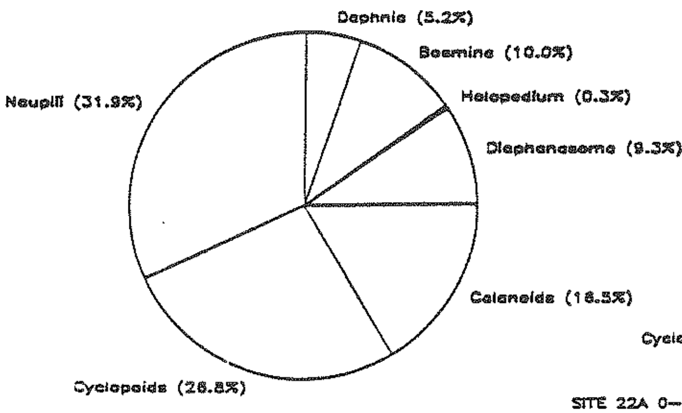
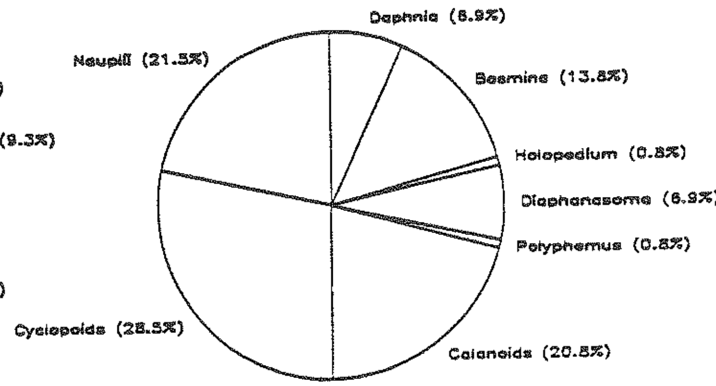

MACROZOOPLANKTON DENSITY
LAKE SUNAPEE 1986
DENSITY (Number per Liter)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
5.1
8.4
13.2
22 0-12m
22A 0-13m
22B 0-9.5m
STATION / DEPTH OF SAMPLE
Sm. Herbivores
Lg. Herbivores
Carnivores

Figure 20. Lake Sunapee 1986. Relative percent by macrozooplankton group (pie diagrams) for each deep site, and macrozooplankton densities for all deep sites sampled (bar graph) on 2 September . Pie diagrams (counter-clockwise from top-left) are 2 September, 0-21.5 meters tow, site 22; 2 September, 0-17.5 meters tow, site 22A; and 2 September, 0-16 meters tow, site 22B. Total height of bar is the number of organisms per liter for each date/depth of tow combination sampled. Each subsection of the bar represents numbers of small herbivores, large herbivores and carnivores as indicated (from bottom to top respectively). Macrozooplankton counted were those that could be captured in a 150 micrometer mesh-size plankton net.

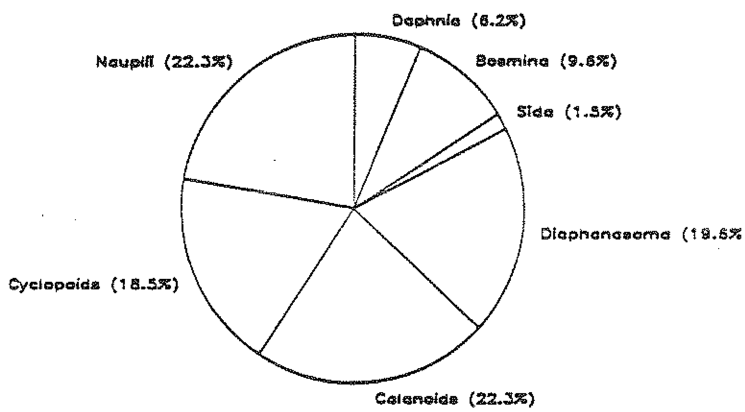
SITE 22 0—21.5m 9/2/86



SITE 22B 0—16m 9/2/86

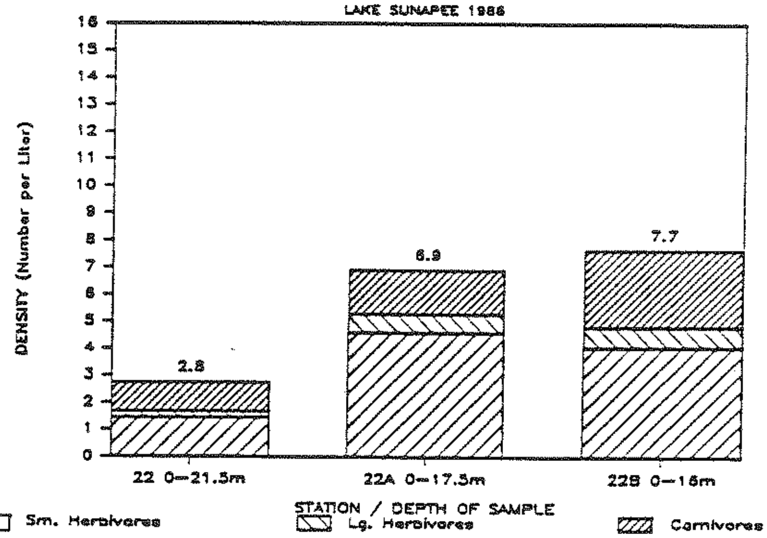


SITE 22A 0—17.5m 9/2/86



MACROZOOPLANKTON DENSITY

LAKE SUNAPEE 1986



Appendix A : Data Listing for 1986 Lake Sunapee Sampling

Sunapee Lake: 3-Jul-86, 1000 - 1600 h. FBG Trip (A. Baker, J. Schloss, L. Sommer, S. Thomas). Boat escort: Courtland Cross. Tributary escort: Jon Cassista.

Site	Z (m)	pH	Alkalinity: gray (mgCaCO3/L)	pink	Spec. Cond. (18 C)	CO2 (mg/L)	Chla (mg/m3)	Color (A440)	Total Phos. (ppb)
2		6.8	3.4	3.8	56.8		0.6	.023	10.0
3		6.7	3.5	3.8	55.9		2.6	.023	11.0
4		6.8	3.4	3.9	56.9		0.7	.031	13.5
5		6.8	3.6	4.0	57.0		0.9	.023	11.5
6		6.9	3.5	4.0	55.9		1.7	.025	12.0
7		6.9	3.6	4.0	56.3		---	.020	11.5
8		6.9	3.6	4.1	56.2		1.9	.022	11.0
9		6.9	3.5	4.0	55.8		1.4	.040	12.0
10		6.8	3.6	4.0	56.0		---	.018	11.0
11		6.8	3.5	4.1	55.1		0.4	.023	12.0
12		6.8	3.4	3.9	56.0		---	.027	11.5
13		6.8	2.9	3.4	55.3		1.0	.031	14.0
14		6.8	3.6	4.1	55.0		1.9	.013	11.5
15		6.8	3.6	4.0	55.9		---	.017	15.5
16		6.8	3.7	4.0	55.8		2.3	.016	14.0
17		6.8	2.9	3.3	55.6		0.8	.026	11.5
18		6.8	3.6	3.9	55.0		1.5	.015	10.0
19		6.8	3.7	4.1	56.2		2.0	.026	13.5
19A		6.8	3.4	3.8	55.5		1.2	.023	13.0
20		6.8	3.2	3.7	55.5		0.9	.012	13.5
21		6.7	2.8	3.2	55.9		0.9	.024	12.0
22		---	3.2	3.7	----	1.8	---	----	11.0
22	10	6.8	3.3	3.6	56.5	13.1	---	----	16.0
22	20	6.3	3.2	3.7	55.0	24.3	---	----	22.5
22A		6.8	3.5	3.8	55.8	7.5	---	----	---
22A	10	---	2.6	2.9	----	9.5	---	----	17.0
22A	17	6.5	4.0	4.4	56.6	25.6	---	----	11.5
22B		6.8	3.4	3.7	56.6	3.7	2.0	.026	12.0
22B	8	7.0	3.6	4.1	53.4	4.1	---	----	---
22B	11	---	3.6	4.1	62.8	2.3	---	----	14.0
23		6.8	3.5	3.9	56.1		0.7	.014	9.5
24		6.8	2.8	3.2	56.8		0.6	.018	11.0
25		6.9	2.9	3.3	57.1		1.1	.013	11.0

Tributaries and Outlet (T-7):

Site	pH	gray	pink	Spec. Cond.	Total Phos.
T-1	6.9	3.7	4.2	54.7	11.0
T-2	---	---	---	66.3	29.5
T-3	---	4.1	4.6	96.5	8.0
T-4	6.4	---	---	46.8	38.0
T-5	6.0	1.5	2.3	27.0	24.5
T-6	6.6	2.6	3.0	34.4	11.0
T-7	6.6	2.6	3.0	75.2	24.5
T-8	6.9	15.7	16.7	627.0	13.5

* ppb(parts per billion) are equivelent to u/L(micrograms/Liter)

Sunapee Lake 3-July-86:Profiles of light intensity measured with a Whitney-type, cosine corrected underwater irradiance meter that measures diffuse downwelling light intensity.

	Meter reading			Intensity relative to Surface		
Depth	Site 22	Site 22A	Site 22B	Site 22	Site 22A	Site 22B
0	60	40	78	100	100	100
0.5	46	28	62	77	70	79
1	36	17	48	60	43	62
1.5	30	10	38	50	25	49
2	28	8.8	30	47	22	38
2.5	23	7.0	28	38	18	36
3	20	6.0	24	33	15	31
3.5	18	5.0	22	30	13	28
4	14	4.2	20	23	11	26
4.5	10	3.6	18	17	9	23
5	9	2.5	16	15	6	20
5.5	8	2.0	13	13	5	17
6	7.4	1.1	11	12	3	14
6.5	6.7	0.9	7.0	11	2	9
7	6.0			10		
8			6.0			8
8.5			5.4			7

Sunapee Lake 3-July-86 Profiles of temperature and dissolved oxygen. Very windy; no anchor; attempted hold with outboard unsuccessful, posted depths are probably overestimates especially at 22, also at 22B to the south, and to a much lesser extent 22A to the north (less wind at latter site). Rain squalls hit us at all three deep sites.

	Site 22		Site 22A		Site 22B	
Depth	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
0	18.2	9.6				
0.5	18.2	9.5	18.1	9.4	18.0	9.3
1			18.1	9.2	18.0	9.3
2	18.2	9.8				
3					18.0	8.9
5	18.1	7.4	18.1	9.2	18.0	6.9
7					18.0	2.4
9					17.5	2.2
10	17.3	4.2	15.5	5.2		
11					16.8	1.8
13	17.1	2.8			14.0	1.9
15	13.0	2.7	7.0	3.8		
20	11.2	2.2	5.8	2.8		
25	10.2	1.6				

Sunapee Lake: 3-July-86 Total Coliform Bacteria Counts.
100 ml sampled; Type HA .45 micron filter MF Endo Broth
24hr incubation at 35 C; samples counted 4-July-86.

Site	Noncoliform	Coliform
2	52	3
3	TNTC	6
4	45	CG
5	26	4
6	8	2
7	34	3
8	TNTC	6
9	84	5
10	31	CG
11	67	7
12	130	5
13	49	2
14	46	5
15	83	6
16	68	5
17	74	7
18	85	6
19	38	3
19A	16	<1
20	63	9
21	49	6
22	12	2
22A	13	<1
22B	28	3
23	14	1
24	27	1
25	65	3
T1	50	11
T2toT5	TNTC	TNTC
T6	TNTC	55
T7	TNTC	TNTC
T8	TNTC	42

CG= Confluent Growth   TNTC= Too Numerous To Count

Sunapee Lake: 3-Aug-86, 1030 - 1600 h. FBG Trip (J. Schloss, L. Sommer, S. Thomas, T. Kenealy). Boat escort: Courtland Cross, Frank Hammond.

Site	Z (m)	pH	Alkalinity: gray (mgCaCO3/L)	pink	Spec. Cond. (18 C)	CO2 (mg/L)	Chla (mg/m3)	Color (A440)	Total Phos. (ppb)
2		6.9	4.1	4.6	73.9		0.5	.006	0.5
3		7.0	4.1	4.6	68.9		0.6	.008	2.0
4		6.8	4.0	4.4	70.6		0.4	.007	2.0
5		6.9	4.1	4.5	70.9		0.4	.008	1.5
6		6.9	4.0	4.5	71.3		0.3	.004	0.5
7		6.9	4.1	4.6	72.6		0.5	.005	1.0
8		6.9	4.1	4.7	71.5		0.5	.004	1.0
9		6.9	4.2	4.5	70.5		0.4	.005	1.0
10		6.9	4.0	4.4	71.2		0.4	.005	2.5
11		6.8	3.7	4.4	70.7		0.4	.008	2.0
11A		6.9	4.0	4.6	71.5		0.4	.006	2.0
12		6.8	4.0	4.4	70.5		0.4	.005	1.0
13		6.8	3.8	4.3	69.9		0.3	.005	1.5
14		6.9	3.8	4.4	69.9		0.3	.005	1.0
15		6.8	3.9	4.3	69.9		0.4	.005	0.5
16		7.0	3.8	4.3	70.6		0.5	.007	2.5
17		6.8	3.8	4.2	70.0		0.4	.008	2.5
18		6.8	3.9	4.4	71.7		0.3	.004	2.5
19		6.9	4.1	4.6	70.0		0.3	.006	2.5
19A		6.9	4.0	4.5	70.6		0.6	.006	2.5
20		6.8	4.0	4.4	70.3		0.4	.005	3.5
21		6.9	3.9	4.6	70.0		0.4	.006	2.0
22		---	4.0	4.5	----	1.2	0.3	.006	2.5
22	6	6.9	3.3	3.6	69.3	0.9	---	----	2.0
22	13	6.4	3.2	3.7	71.5	3.8	---	----	3.5
22A		6.8	3.9	4.2	71.9	1.2	0.3	.006	4.0
22A	6	6.9	3.9	4.3	71.9	0.8	---	----	3.5
22A	15	6.2	4.1	4.6	72.8	5.4	---	----	4.0
22B		6.8	4.0	4.5	70.2	1.1	0.1	.006	3.5
22B	5	6.8	4.9	4.3	70.2	2.4	---	----	3.5
22B	9.5	6.8	3.5	3.8	70.3	2.4	---	----	4.0
23		6.8	3.9	4.5	69.9		0.4	.006	2.0
24		6.9	4.2	4.5	72.0		0.4	.016	2.0
25		6.9	4.1	4.8	73.3		0.5	.011	2.5

Tributaries and Outlet (T-1):

T-1		6.9	1.7	2.0	68.3		0.4	.027	4.5
T-2		7.0	5.2	5.6	102.1		0.6	.034	3.5
T-3		7.1	8.5	8.8	57.1		0.3	.053	4.0
T-4		6.7	5.1	5.6	68.9		0.4	.128	4.5
T-5		5.8	3.0	3.4	47.8		15.3	.074	6.0
T-6		6.6	2.5	2.8	32.6		0.0	.010	5.0
T-7		6.6	4.0	4.3	42.4		0.2	.030	4.0
T-8		7.2	19.6	20.1	457.1		0.4	.044	2.0

* ppb(parts per billion) are equivelent to ugm/L(micrograms/Liter)

Sunapee Lake 3-Aug-86: Profiles of light intensity measured with a Whitney-type, cosine corrected underwater irradiance meter that measures diffuse downwelling light intensity.

	Meter reading			Intensity relative to Surface		
Depth	Site 22	Site 22A	Site 22B	Site 22	Site 22A	Site 22B
0.1	100	100	92	100	100	100
0.5	76	66	80	76	66	87
1	68	46	58	68	46	63
2	48	38	46	48	38	50
3	35	27	36	35	27	39
4	25	20	24	25	20	26
5	20	14	20	20	14	22
6	16	9.8	17	16	9.8	18
7	12	5.5	14	12	5.5	15
8	4	3.6	12	4.0	3.6	13
9	1.8	2.5	10	1.8	2.5	11
10	1.1	2.2	9	1.1	2.2	9.8
10.5			6			6.5
11	0.5	1.5	0.5	1.5		
12		0.6		0.6		
13		.48		0.48		
14		.26		0.26		
15		.21		0.21		
16		.10		0.21		

Sunapee 3 August 1986-Profiles of temperature and dissolved oxygen. Calm and sunny for sites 22A and 22B wind started picking up late afternoon during sampling at site 22. Boat was anchored at all deep sites.

	Site 22		Site 22A		Site 22B	
Depth	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
0.1	24.0	8.6	23.5	8.5	23.0	9.0
0.5	23.0	8.6	23.0	8.6		8.8
1.0		8.5		8.3	26.0	
2.0		8.6		8.0		
3.0		8.5		7.9		
3.5	22.0	8.5				
4.0		8.3			26.0	8.6
5.0		8.2		7.5		
5.5			22.5	6.6		
6.0		8.0	22.0	7.3	25.5	8.6
7.0	21.0	7.8		5.6		8.4
7.5		7.5	21.5	5.0		
8.0	20.0	7.4	20.0			8.1
8.5	19.0	7.2	19.0	4.7	24.0	7.6
9.0	18.5		18.0	4.6	22.5	7.7
9.5					22.0	7.5
10.0	16.5	7.1	16.5	4.5		7.3
10.5						6.9
11.0	15.5	6.3	14.5	4.0		
12.0	13.5	6.0	11.5	3.8		
13.0			11.0	3.3		
13.5	12.0	5.0				
14.0		4.7		3.2		
15.0				3.0		
15.5				2.8		
16.0						

Sunapee Lake: 3-August-86 Fecal Coliform Bacteria Counts.
100 ml sampled; Type HA .45 micron filter MFC Endo Broth
24hr incubation at 44.5 C; samples counted 4-August-86.

Site	Noncoliform	Fecal Coliform
2	--	-
3	1	1
4	1	<1
5	<1	<1
6	<1	<1
7	<1	1
8	<1	<1
9	<1	2
10	<1	3
11	<1	<1
11A	<1	2
12	1	3
13	1	<1
14	19	1
15	19	1
16	15	7
17	4	3
18	8	<1
19	<1	2
19A	<1	2
20	<1	1
21	<1	<1
22	1	<1
22A	<1	<1
22B	15	3
23	<1	<1
24	<1	1
25	2	1
T1	3	2
T2	17	3
T3	6	28
T4	1	24
T5	1	15
T6	13	1
T7	237	21
T8	46	60

CG= Confluent Growth   TNTC= Too Numerous To Count

Sunapee Lake: 2-Sep-86, 1000 - 1600 h. FBG Trip (J. Schloss, L. Summer, D.Fuhlendorf , Z. Gho) . Boat escort: Courtland Cross.

Site	Z (m)	pH	Alkalinity: gray (mgCaCO3/L)	pink	Spec. Cond. (18 C)	CO2 (mg/L)	Chla (mg/m3)	Color (A440)	Total Phos. (ppb)
1		6.6	3.5	4.4	72.4		1.0	.007	3.5
2		6.8	3.2	4.3	71.9		1.3	.007	1.0
3		6.8	3.3	4.2	70.9		1.1	.009	1.5
4		6.9	3.4	4.5	71.3		0.6	.009	0.5
5		6.9	3.3	4.2	71.7		0.8	.007	1.5
6		6.8	3.5	4.3	71.9		0.9	.008	3.5
7		6.9	3.4	4.5	70.8		0.6	.007	1.5
8		6.9	3.5	4.3	70.7		0.9	.007	0.5
9		6.8	3.3	4.2	71.8		0.8	.008	1.5
10		6.9	3.4	4.2	71.5		0.9	.011	2.0
11		6.8	3.4	4.1	70.7		0.9	.007	2.0
11A		6.8	3.4	4.2	71.8		0.8	.009	1.5
12		6.8	3.2	4.4	70.0		0.8	.015	0.5
13		6.8	3.4	4.1	71.1		0.8	.007	1.5
14		6.4	3.0	3.8	81.4		0.9	.007	2.5
15		6.8	3.4	4.2	71.2		1.0	.008	1.5
16		6.1	3.3	4.1	71.3		1.1	.009	0.5
17		6.8	3.5	4.2	71.4		1.4	.015	1.5
18		6.7	3.4	4.1	70.7		0.7	.008	2.0
19		6.7	3.2	4.0	70.8		0.7	.008	1.5
19A		6.8	3.5	4.4	71.3		0.6	.008	1.5
20		6.9	3.3	4.0	71.3		0.9	.008	0.5
21		6.9	3.3	4.1	72.0		0.6	.008	1.5
22	0.5	6.9	3.3	4.0	71.6	1.0	1.4	.007	1.0
	6.0	6.9	3.3	4.2	70.9	1.2			4.5
	11.5	6.4	3.4	4.2	71.3	2.4			3.0
	16 0	6.0	3.5	4.6	72.1	8.0			2.0
22A	0.5	6.7	3.3	4.1	71.1	0.9	0.6	.008	1.0
	6.0	6.7	3.3	4.1	71.4	0.9			1.5
	14.0	6.4	3.4	4.7	71.4	1.9			3.0
	16.0	4.6	3.4	4.4	72.1	7.0			2.5
22B	0.5	6.7	3.2	4.1	68.5	1.0	1.7	.006	0.5
	6.0	6.8	3.4	4.2	70.7	1.2			3.5
	12.0	6.5	3.4	4.1	69.3	2.2			3.0
	22.0	5.9	3.4	4.2	75.0	7.6			2.5
23		6.9	3.4	4.3	71.2		0.7	007	1.0
24		6.8	3.5	4.6	71.0		1.3	.013	1.0
25		6.8	3.3	4.4	73.2		1.0	.009	1.5
Tributaries and Outlet (T-1):									
T-1		7.1	.05	0.1	84.5		1.1	.007	2.0
T-2		7.1	1.3	1.5	108.8		1.4	.018	1.5
T-3		7.1	10.6	11.2	107.5		1.1	.017	1.5
T-4		7.1	7.5	8.0	81.8		1.7	.076	4.0
T-5		7.1	3.3	3.7	71.7		1.1	.015	1.5
T-6		7.1	4.4	4.9	54.2		0.7	.006	4.0
T-7		7.1	7.3	8.1	96.7		1.4	.033	1.5
T-8		7.0	21.8	22.6	108.4		1.4	.013	1.5

* ppb(parts per billion) are equivelent to ugm/L(micrograms/Liter)

2-Sept-86 Profiles of light intensity measured with a Whitney-type, cosine corrected underwater irradiance meter that measures diffuse downwelling light intensity.

	Meter reading			Intensity relative to Surface		
Depth	Site 22	Site 22A	Site 22B	Site 22	Site 22A	Site 22B
0.1	90	95	100	100	100	100
0.5	72	74	78	80	78	78
1	60	57	59	67	60	59
2	51	40	48	57	42	48
3	38	30	30	42	32	30
4	29	26	24	32	27	24
5	25	22	18	28	23	18
6	19	16	14	21	17	14
7	15	13	11	17	14	11
8	12	10	6	13	10.5	6.0
9	9.1	5.2	4.6	10	5.5	4.6
10	5.8	3.6	3.6	6.4	3.8	3.6
11	3.9	2.5	2.8	4.3	2.6	2.8
12	2.4	1.7	2.1	2.7	1.8	2.1
13	1.5	1.3	1.7	1.7	1.4	1.7
14	1.0	0.8	1.3	1.1	0.84	1.3
.15	0.53		1.0	0.59		1.0
16			0.56			0.56

Sunapee 2-Sep-1986-Profiles of temperature and dissolved oxygen. Calm and sunny for site 22B clouds moved in early afternoon at site 22 and then cleared during sampling of site 22A. Boat was anchored at all deep sites.

	Site 22		Site 22A		Site 22B	
Depth	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
0.1	20.0	9.2	20.5	8.8	19.0	9.4
0.5	19.0	9.2	20.3	8.6	19.0	9.1
1.0	19.5	9.0	20.1	8.9	19.0	9.2
2.0	19.5	8.9	19.8	8.8	19.0	9.3
3.0	19.0	8.9	19.5	8.8	18.8	9.0
4.0	19.0	8.8	19.0	8.9	18.8	9.3
5.0	19.0	8.5	18.9	8.9	18.8	9.4
6.0	19.0	8.0	18.8	8.8	18.8	9.3
7.0	19.0	7.7	18.5	8.8	18.7	9.3
8.0	19.0	7.0	18.5	8.6	18.5	9.1
9.0	18.5	6.5	18.5	8.3	18.5	8.8
10.0	18.5	6.1	18.2	8.1	18.2	8.2
11.0	18.0	5.7	18.0	7.9	18.2	8.3
11.5	16.0	3.7	15.1	6.8		
12.0	15.0	3.4	14.8	6.0	18.2	8.1
12.5	14.0	3.2	13.4	5.2		
13.0	13.0	2.8	12.5	4.7	18.0	7.8
13.5			12.0	4.3	16.5	6.7
14.0	12.0	2.7	12.0	4.2	14.7	5.7
14.5					12.0	5.0
15.0	11.5	2.6	11.4	3.9	11.0	5.8
15.5					10.5	4.5
16.0	11 0	2.4	11.1	3.6	10 4	4.3
16.5					10.0	3.7
17.0	10.5	2.2	11.0	3.4		
18.0	10.0	2.0	10.9	3.1		
18.5			10.8	2.1		
19.0	10.0	2.0				
21.0	10.0	1.8				
22.0	10.0	1.6				
22.5	10.0	1.4				

Sunapee Lake: 2-Sept-86 Coliform Bacteria Counts.
50 to 100 ml sampled; Type HA .45 micron filter MF-C Broth
24hr incubation at 44.5 C for Fecal Coliform; M-Endo MF Broth 24hr incubation at 35 C for Total Coliform. Samples counted 3-Sept-86.

Site	Total Coliform	Fecal Coliform	Noncoliform
1	6	2	*
2	-	<1	*
3	7	1	TNTC
4	-	-	-
5	-	<1	-
6	-	<1	-
7	<1	<1	<1
8	-	<1	-
9	-	-	-
10	-	<1	-
11	-	<1	-
11A	-	-	-
12	-	<1	-
13	-	-	-
14	<1	<1	730
15	-	<1	-
16	<1	1	*
17	<1	<1	*
18	1	<1	TNTC
19	-	<1	-
19A	-	-	-
20	-	1	-
21	<1	<1	TNTC
22	-	<1	-
22A	-	<1	-
22B	<1	-	<1
23	<1	-	*
24	2	1	604
25	-	<1	-
T1	4	<1	*
T2	<1	<1	TNTC
T3	26	8	*
T4	10	8	TNTC
T5	<1	<1	*
T6	<1	<1	*
T7	76	42	*
T8	18	22	TNTC

TNTC= Too Numerous To Count
* = Samples had high #s of Non-Coliform (between 400 and 1000 cells/100ml). Total Coliform are most likely more than that measured due to overcrowding on the filter.

Appendix B: How to find the tributary sampling points:

T-1 Outlet at Sunapee Harbor. Collect from one of the docks just upstream from the screens. Also record the gauge height. (10.3 on 3-Jul-86)

T-2 Near T-3, but on lakeside. Walk 25 m down drive, collect just below small bridge.

T-3 Culvert across Rte. 11 from the lake, near Rte. 103-A.

T-4 On 103-A, look for crossroad sign, then sign for Soo Nipi Park. Go right, then 200 m, take left, cross small bridge. Collect there if lake is low, otherwise drive another 20 m, park on left, hike through the woods to the stream where there is reasonable flow (not lakewater).

T-5 Take a right from 103-A at the Blodgetts Landing sign. Then take a left at Bowles Road. Sample taken 10m from road opposite lakeside.

T-6 Pine Cliff: Continue on Bowles Road till 103-A. Turn right (south) and continue to Cloverfield Road (sign hidden by large pine until you are on top of it). Go right.

T-7 Go south to stop sign, then right onto Rte. 103, continue to traffic circle, follow signs to State Beach.

T-8 On route 103-A (east side of lake) where stream crosses onto C. Cross's property.

APPENDIX C

GLOSSARY

Aerobe Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae See phytoplankton.

Alkalinity Total concentration of bicarbonate and hydroxide ions (in most lakes). (See Buffering).

Anaerobe Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic Referring to the bottom sediments.

Bacterioplankton Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the main chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride	One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.
Chlorophyll a	The main green pigment in plants. The concentration of chlorophyll a in lakewater is often used as an indicator of algal abundance.
Circulation	The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.
Density	The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.
Dimictic	The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).
Dystrophy	The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll a concentration may be low or high.
Epilimnion	The uppermost layer of water during periods of thermal stratification. (See lake diagram).
Eutrophy	The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi disk depth, high chlorophyll a, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO2 — Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis — The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic acids — Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen ion — The "acid" ion, present in small amounts even in distilled water, but contributed to rainwater by atmospheric processes, to groundwater by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion — The deepest layer of lakewater during periods of thermal stratifiction. (See lake diagram)

Lake — Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, lochs, billabongs, bogs, marshes, etc.

Lake morphology — The shape and size of a lake and its basin.

Meromixis — The condition where the entire lake fails to circulate to its deepest point; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy — The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll _a_, secchi disk depth, and total phosphorus are also moderate. These lakes are esthetically 'fair' but not as good as oligotrophic lakes.

Metalimnion — The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree Celsius per meter depth. Also called the thermocline.

Mixis — Periods of lakewater mixing or circulation.

Mixotrophy — The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll a values are also high.

Oligotrophy — The lake trophic state where algal production is low, Secchi disk depth is deep, and chlorophyll a and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn — See circulation or mixis.

pH — A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10-5 molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14.

Photosynthesis — The process by which plants convert the inorganic substance carbon dioxide into organic glucose (sugar) using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton — Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million — Also known as PPM. This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 PPM of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion — Also known as ppb. This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb of phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton — Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated — When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific conductivity — A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum — A layer or a "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind. (See Appendix B.)

Thermocline Region of temperature change. (See metalimnion.)

Total Phosphorus A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic status A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories, and Appendix B)

Z A symbol used by limnologists as an abbreviation for depth.

Zooplankton Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia*, *Cyclops*, *Bosmina*, and *Kellicottia*.